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EVALUATING COMMERCIAL NOZZLES FOR USE ON BOARD MERCHANT VESSELS

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16. Abstract

The purpose of this test series was to evaluate commercial nozzles and the Coast Guard approved all-purpose nozzle to determine the most effective nozzle for shipboard firefighting. The specific objectives were to evaluate range, patterns and debris-passing capabilities; evaluate effectiveness in providing protection to the nozzle operator; and evaluate effectiveness in combating deck and compartment fires.

Commercial nozzles meeting certain specifications should be permitted for use on board merchant vessels as the test results indicated they were more effective than the Coast Guard all-purpose nozzle in the various phases of testing.

The traditional shipboard firefighting method of having two hose line teams in which the first team fights the fire and the second team only protects the first team should be modified to take full advantage of the commercial nozzles' capabilities.

Compartment fires should be vented to provide an avenue for the firefighter to remove the smoke, heat and steam so he may advance to the fire for its extinguishment. With or without venting, the firefigher should stay low, advance to the fire and use limited water for its extinguishment as the production of steam can force his withdrawal.

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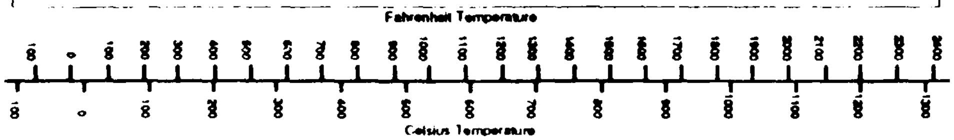
Conversions to Metric Measures

When you know (symbol)	Multiply by	To find (symbol)
Length		
inches (in)	2.540	centimeters (cm)
feet (ft)	30.48	centimeters (cm)
feet (ft)	0.3048	meters (m)
Area		
square inches (in^2)	6.452	square centimeters (cm^2)
square feet (ft^2)	929.0	square centimeters (cm^2)
square feet (ft^2)	0.09290	square meters (m^2)
Volume		
fluid ounces, US (fl oz)	29.57	milliliters (ml); cubic centimeters (cm^3)
gallons, US liquid (gal)	3.785	liters (l)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
Mass (weight)		
ounces, avoirdupois (oz)	28.35	grams (g)
pounds (lb)	0.4536	kilograms (kg)
Density		
pounds per cubic inch (lb/in^3)	27.68	grams per cubic centimeter (g/cm^3)
pounds per cubic foot (lb/ft^3)	16.02	kilograms per cubic meter (kg/m^3)
Pressure		
pounds per square inch (psi)	6895	pascals (Pa); newtons per square meter (N/m^2)
pounds per square inch (psi)	0.0703	kilograms per square centimeter (kg/cm^2)
pounds per square inch (psi)	51.71	millimeters of mercury (mm Hg) at 0°C
pounds per square inch (psi)	0.06895	bars (10^5 N/m^2)
inches of water (in H_2O) at 60°F	1.867	millimeters of mercury (mm Hg) at 0°C
inches of water (in H_2O) at 60°F	248.9	pascals (Pa)
inches of water (in H_2O) at 60°F	0.002489	bars (10^5 N/m^2)
inches of mercury (in Hg) at 32°F	3386	pascals (Pa)
inches of mercury (in Hg) at 32°F	0.03386	bars (10^5 N/m^2)
Energy		
British thermal units (Btu)	1055	joules (J); newton-meter (Nm)
British thermal units (Btu)	0.2520	kilocalories (kcal)
Thermal Conductance		
Btu / hr - ft^2 - °F	0.0001356	calories / sec - cm^2 - °C
Btu / hr - ft^2 - °F	0.4882	calories / hr - cm^2 - °C
Btu / hr - ft^2 - °F	0.0005678	watts / cm^2 - °C
Heat Flow		
Btu / hr - ft^2	0.00007535	calories / sec - cm^2
Btu / hr - ft^2	0.2712	calories / hr - cm^2
Btu / hr - ft^2	0.0003154	watts / cm^2



Conversions from Metric Measures

When you know (symbol)	Multiply by	To find (symbol)
Length		
millimeters (mm)	0.03937	inches (in)
centimeters (cm)	0.3937	inches (in)
meters (m)	39.37	inches (in)
Meters (m)	3.281	feet (ft)
Area		
square centimeters (cm^2)	0.1550	square inches (in^2)
square centimeters (cm^2)	0.001076	square feet (ft^2)
square meters (m^2)	1550	square inches (in^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)
Volume		
milliliters (ml)	0.03381	fluid ounces, US (fl oz)
liters (l)	0.2642	gallons, US liquid (gal)
liters (l)	0.03531	cubic feet (ft^3)
cubic centimeters (cm^3)	0.06102	cubic inches (in^3)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
Mass (weight)		
grams (g)	0.03527	ounces, avoirdupois (oz)
grams (g)	0.002205	pounds (lb)
kilograms (kg)	2.205	pounds (lb)
Density		
grams per cubic centimeter (g/cm^3)	0.03613	pounds per cubic inch (lb/in^3)
kilograms per cubic meter (kg/m^3)	0.06243	pounds per cubic foot (lb/ft^3)
Pressure		
pascals (Pa); newtons per sq. meter (N/m^2)	0.000145	pounds per square inch (psi)
bars (10^5 N/m^2)	14.50	pounds per square inch (psi)
kilograms per square centimeter (kg/cm^2)	14.22	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.01934	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.5357	inches of water (in H_2O) at 60°F
bars (10^5 N/m^2)	401.8	inches of water (in H_2O) at 60°F
pascals (Pa)	0.00402	inches of water (in H_2O) at 60°F
pascals (Pa)	0.000295	inches of mercury (in Hg) at 32°F
bars (10^5 N/m^2)	29.53	inches of mercury (in Hg) at 32°F
Energy		
kilojoules	0.9478	British thermal units (Btu)
kilocalories	3.968	British thermal units (Btu)
Thermal Conductance		
calories / sec - cm^2 - °C	7373	Btu / hr - ft^2 - °F
watts / cm^2 - °C	1761	Btu / hr - ft^2 - °F
Heat Flow		
calories / sec - cm^2	13270	Btu / hr - ft^2

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1.0 OBJECTIVES

The purpose of this test series was to evaluate commercial nozzles and the Coast Guard approved all-purpose nozzle to determine the most effective nozzle for shipboard firefighting. This evaluation utilized full-scale fire tests, nonfire flow and spray pattern tests, and the results of previous work by the Coast Guard.

The specific objectives were to evaluate:

(1) range and patterns
(2) debris-passing capabilities
(3) effectiveness in providing protection for the nozzle operator
(4) effectiveness in controlling and extinguishing deck fires and compartment fires.

2.0 BACKGROUND

2.1 Commercial Nozzles

In the past ten years commercial nozzles have been improved through technology to increase their firefighting capabilities. These improvements include tighter straight streams, adjustable fog patterns, and nozzles with adjustable flow settings. Other improvements include nozzles which automatically increase or reduce the tip opening as the flow rate fluctuates, the use of flush settings, and nozzles constructed with lightweight alloys and plastics.

Today, manufacturers contend that commercial nozzles are superior in design and performance when compared to the Coast Guard approved all-purpose nozzle for use on merchant vessels. They do indicate, however, that not all commercial nozzles are designed or constructed for marine firefighting. Nozzles often proposed for shipboard acceptance are typically designed for use at shore side facilities by professional firefighters. They have adjustable flow settings and are not designed for use with the Coast Guard applicator. The marine requirements and firefighting capabilities of these nozzles have never been completely compared to those of the Coast Guard nozzle and its applicator. Presently, commercial nozzles are not approved for use on merchant vessels since they do not meet present Coast Guard regulations.

2.2 Nozzle Testing

Nozzle manufacturers have never published final reports that would document the superiority of commercial nozzles over the Coast Guard all-purpose nozzle. A literature search on nozzle testing was performed by the largest database center in the United States. Two reports (References 1, 2) were found which indicated comparative fire testing had been performed on

several models of commercial nozzles using AFFF on deck fires. The documentation comparing these nozzles suggests that certain questions can be answered from the previous test results but additional fire and nonfire testing was required to satisfy the majority of the objectives listed above.

Several firefighting schools (References 3-9) were contacted, but they could not provide reports which evaluated the commercial nozzles and the Coast Guard all-purpose nozzle. However, two of the firefighting schools, Texas A&M and Exxon's Fire Fighting School, each conducted a test program comparing the performance of different commercial nozzles and the Coast Guard all-purpose nozzle on Class B fires and other tests. Each of the schools have made a videotape which shows the testing and results. The video tapes provide evidence of the commercial nozzles' superiority over the Coast Guard all-purpose nozzle when using water on Class B deck fires while References 1 and 2 indicate the same results when the nozzles use AFFF solution.

2.3 Coast Guard Regulations

Coast Guard equipment approval regulations governing nozzles used on merchant vessels can be found in 46 CFR 162.027 (Reference 10). These regulations are based on shipboard firefighting conditions and contain three fundamental requirements: 1) the nozzles must be able to pass debris of a specified size; 2) they must be suitable for use with a low-velocity fog applicator; and 3) they must be resistant to corrosion. Debris is often found in the fire main system due to foreign matter entering the sea chest and rust forming in the fire main piping.

Presently, an approved 1-1/2 inch nozzle must pass debris the size of a 3/8-inch diameter ball while a 2-1/2 inch nozzle must pass debris the size of a 1/2-inch diameter ball. The low-velocity fog applicator when attached to the nozzle provides cooling protection to firefighters working close to a fire and it permits firefighters to place a fog spray around bulkheads and over coamings without their being exposed to the flames. (All materials used in the construction of the nozzles are required to be corrosion resistant to the marine environment.)

2.4 Fire Main Piping

The fire main piping on merchant ships is supplied with water from a sea chest inside the vessel. The seawater inside the chest often contains debris which has passed through its strainers. From the sea chest, the water is pumped through the fire main system to the nozzles where it can be used. The interior of the fire main system is constantly forming rust and collecting encrustation from the seawater. As this rust and encrustation breaks off, it is funneled to the nozzles when they are used. It is to be expected that nozzles with smaller tip openings would clog up before nozzles with larger tip openings.

U.S. merchant flag vessels are required to have weekly fire drills, to start their fire pumps and to use a number of hydrants to insure that the system is working (for example, for tank ships, Reference 11). This exercise may flush some of the rust and debris to the nozzles where it can be removed before it causes a problem, but the likelihood of rust and debris existing in the piping during an emergency must be accepted and planned for.

3.0 APPROACH

Testing was conducted at the U.S. Coast Guard Fire and Safety Test Detachment in Mobile, Alabama. The approach was to compare the shipboard firefighting effectiveness of the Coast Guard approved all-purpose nozzle and selected commercial nozzles. Full-scale fire tests and nonfire tests were conducted aboard the tank vessel A.E. WATTS at Little Sand Island. Figure 1 shows the location on the test vessel for each type of testing.

The vessel was fitted with fire containment barriers, fire main piping and structural modifications necessary to conduct the various testing. Range, pattern and debris tests were conducted on the main deck. A piping structure (Figure 2) was set up in one of the shallow open test pens on the main deck to conduct LPG (liquefied petroleum gas) fire tests. These LPG fires provided a reproducible, high heat source to evaluate operator protection provided by fog patterns of the different nozzles. A compartment (Figure 3) on the starboard side of the after deck house (01 deck) was used to evaluate nozzle effectiveness in interior fires both in protecting the operator and in control and extinguishment.

This testing investigated nozzle effectiveness of the different 1-1/2 inch nozzles when using the same test pressures and similar flow rates. Three different nozzle pressures were used. A test pressure of 100 psig was selected since it is currently used in Coast Guard approval tests of nozzles (Reference 10). A second test pressure of 75 psig was selected because it is the Coast Guard's minimum operating requirement for the most hydraulically remote hydrant on a tank vessel (Reference 12). A third test pressure of 50 psig was used because it is the Coast Guard's minimum operating requirement for the same location on cargo and passenger vessels (References 13, 14). The nozzles selected for evaluation have similar flow rates at these test pressures. This insured an equal comparison based on similar application rates. Extinguishment time, passage of debris, operator protection, nozzle construction, and ease of operation were the principal criteria used to evaluate nozzle effectiveness.

The testing sequence in each scenario employed randomization and duplication to minimize the effects of bias and random errors in the test results. Randomization was also utilized to isolate errors attributed to different fire types, nozzles and operator

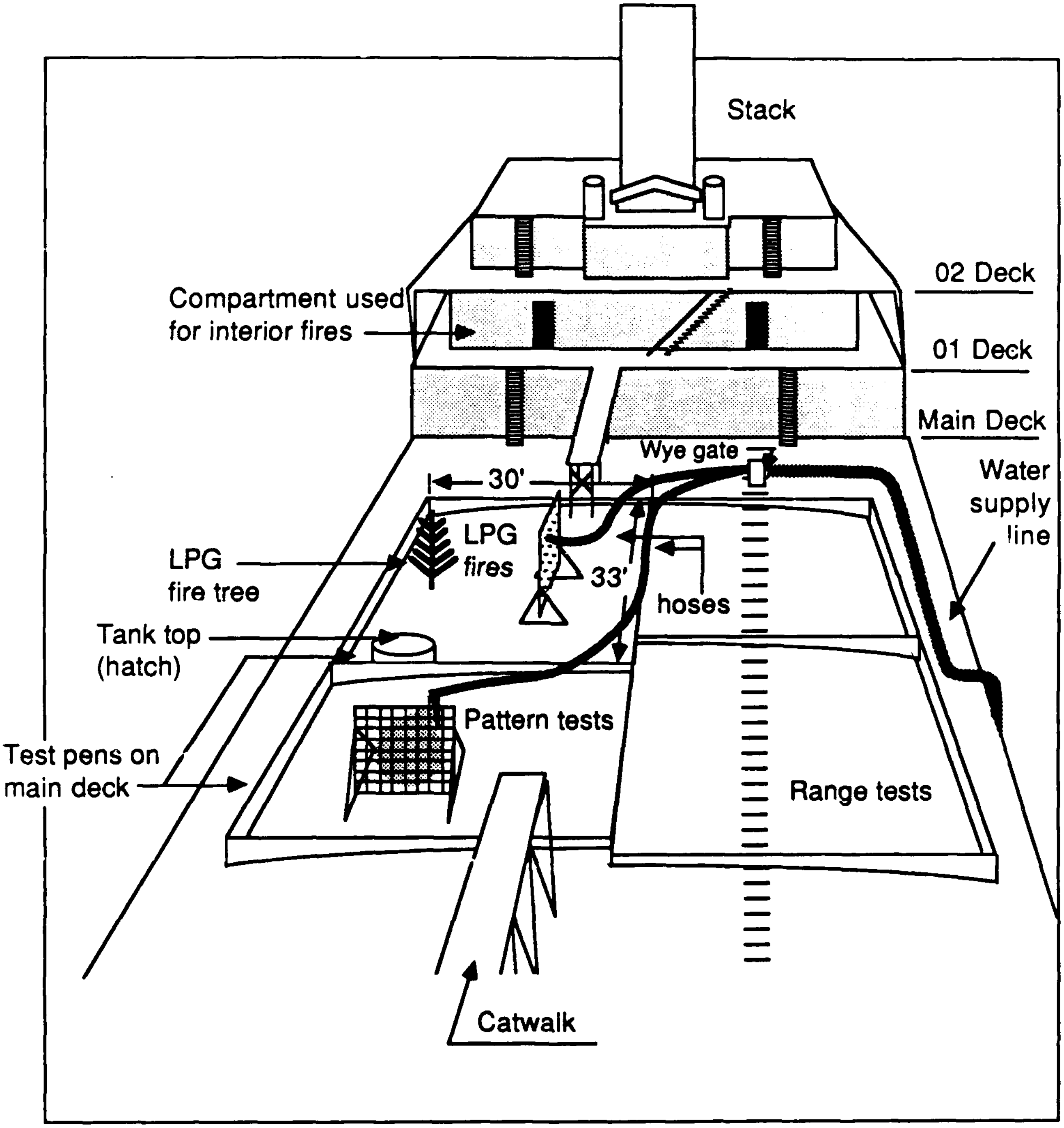


FIGURE 1. TEST AREAS ON TANK VESSEL A.E. WATTS

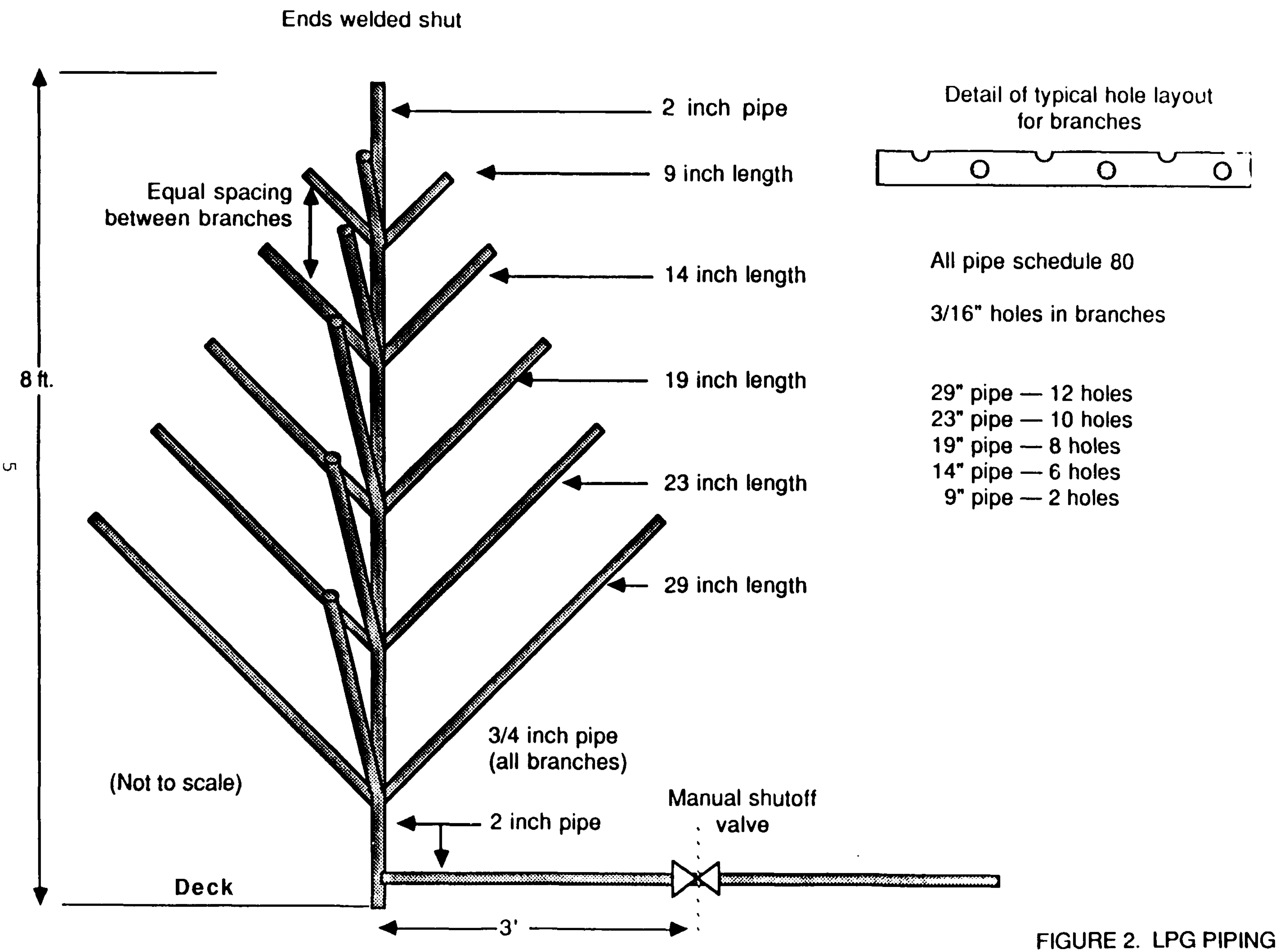


FIGURE 2. LPG PIPING

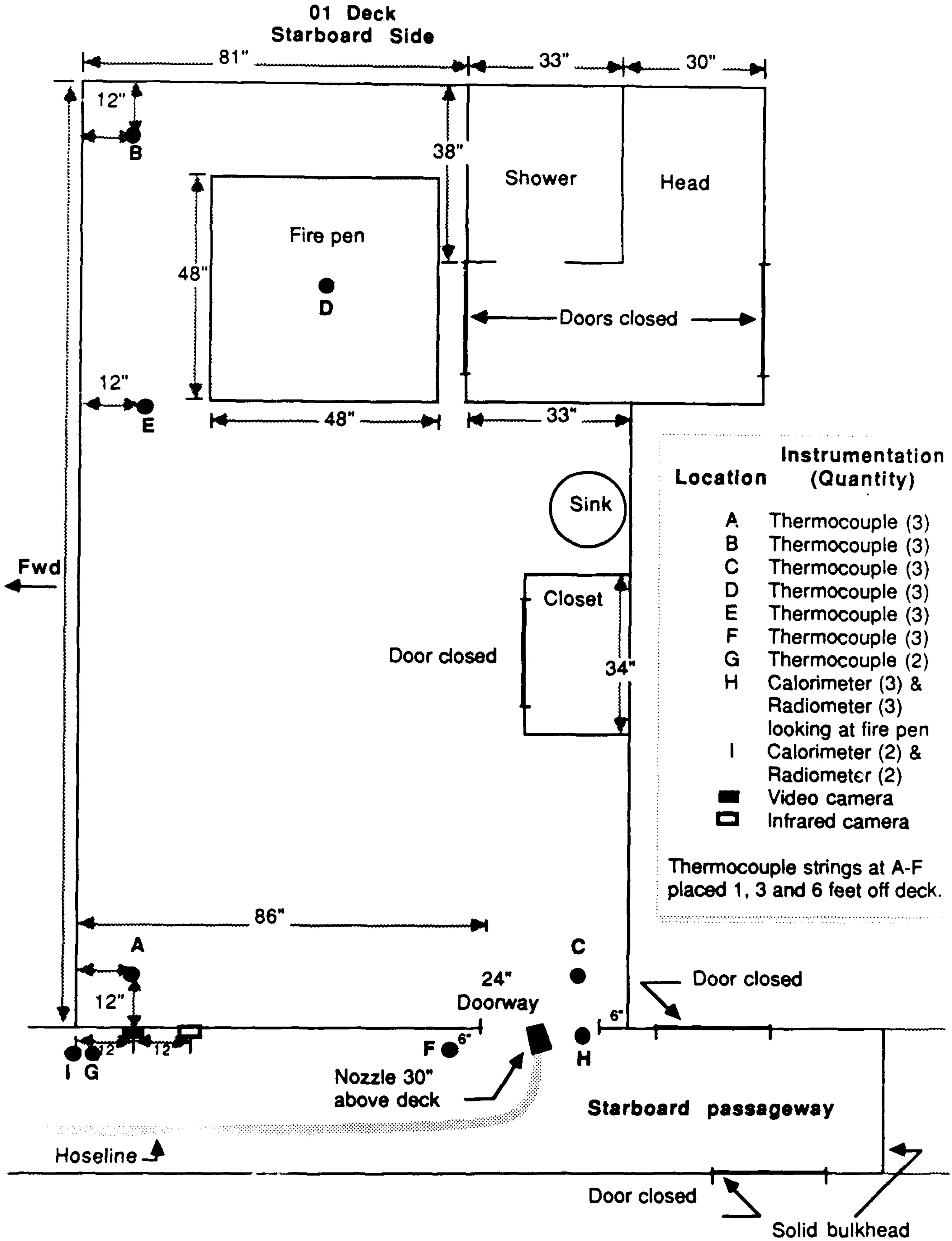


FIGURE 3. TEST COMPARTMENT ON 01 DECK

and environmental factors. Duplicate testing was used to provide confidence in test results.

3.1 Nozzles

The Coast Guard approved 1-1/2 inch all-purpose nozzle (APN) and its applicator were used as the baseline during the evaluation. Nozzle manufacturers were asked to provide 1-1/2 inch nozzles which compared to the Coast Guard APN and applicator for marine firefighting. For marine use, a nozzle should meet certain criteria. It should be constructed of material suited for use in a marine environment; it should be capable of passing the required size of debris either directly or by a flush setting; and it should produce a fog pattern capable of meeting the requirements of the Coast Guard approved fog applicator.

Nine 1-1/2 inch nozzles were compared to the Coast Guard APN and applicator. The nozzles and their design characteristics are listed in Table 1. The test nozzles (except for the Feecon-Navy and one Task Force Tip (TFT)) are shown in Figure 4. Every nozzle did not meet all criteria considered essential for use in marine firefighting but different features dictated that they be included in the testing. Most of the nozzles were of the fixed flow rate design. Automatic nozzles (one TFT and one Elkhart) meeting the selected test application rates were also included in the testing. It should be noted that there are two Akron nozzles of the same basic style but each is designed to provide a different flow rate. One Elkhart SFL nozzle had an adjustable flow setting which permitted the selection of several flow rates. All the TFT nozzles had a distinctive feature: a screen located in the inlet side of the nozzle to prevent debris from reaching the tip. One lightweight plastic nozzle (Feecon-Navy) was also tested.

3.2 Pressure/Flow

In addition to the three nozzle pressures (100, 75, and 50 psig) used in most of the testing, a fourth nozzle pressure (80 psig) was used in a few tests in order to evaluate one nozzle at similar flow rates to the other nozzles. Some nozzles were not evaluated at each pressure in the different types of testing since they did not meet all the requirements for marine firefighting. These nozzles were excluded in order to maximize the amount of data which could be obtained from the limited number of tests to be conducted. The test schedules in Appendixes A, B and C list the pressure and flow used for each nozzle in every test.

3.3 Instrumentation

Color video cameras and recorders were used to document each test. Time-date generators were used with the video recordings. Two 35 mm cameras were used to take slides of each test.

TABLE 1
NOZZLES AND MANUFACTURERS' DESIGN CHARACTERISTICS
(See Figure 4 for illustration of each nozzle)

Figure 4 Reference No.	Nozzle	Flow Selection	Mfgr's Design (psig/gpm)	Length (approx. inches)	Weight (approx. lbs.)	Construction	Pistol Grip Description	Teeth Description	Flush Setting Opening (inches)
1	AKRON 3019	fixed	100/95	8	9	Red brass contruction/ rubber bumper	Rubber over brass handle	Fixed double row of rubber teeth	5/16
2	AKRON 3019M	fixed	100/60	8	9	Red brass construction/ rubber bumper	Rubber over brass handle	Fixed double row of rubber teeth	3/16
3	ELKHART	fixed	100/95	10	9	Brass construction/ rubber bumper	Brass handle	Fixed row of brass teeth	5/16
4	ELKHART SFL-B	variable	100/60	8	9	Brass construction/ rubber bumper	Brass handle	Single row of spinning plastic teeth	5/16
5	ELKHART SM-10-FBC	automatic self-adjust	105/125	9	8	Brass construction/chrome finish/rubber bumper	Brass handle	Single row of spinning plastic teeth	5/16
6	TASK FORCE TIP BGN-125F	automatic self-adjust	80/90	9	3	Alum. alloy construction/ stainless steel valve/ rubber bumper	Alum. alloy handle	Fixed row of rectangular rubber teeth	5/16
7	TASK FORCE TIP BGN-95	fixed	100/95	9	3	Alum. alloy construction/ stainless steel valve/ rubber bumper	Alum. alloy handle	Fixed row of rectangular rubber teeth	5/16
Not Shown	TASK FORCE TIP BGH-60	fixed	100/60	9	3	Alum. alloy construction/ stainless steel valve/ rubber bumper	Alum. alloy handle	Fixed row of rectangular rubber teeth	5/16
Not Shown	FEECON-NAVY	fixed	100/95	8	3	Plastic construction	Plastic handle	Fixed row of rectangular plastic teeth	5/16
8	COAST GUARD ALL-PURPOSE	fixed	st st 100/117	10	9	Brass construction	None	None	5/8
			fog 100/55			Brass construction	None	None	5/16
			applic 100/54	4 ft	5	Galvanized steel	None	Fixed row of metal teeth	5/16
				10 ft	24	Galvanized steel	None	Fixed row of metal teeth	5/16
				12 ft	26	Galvanized steel	None	Fixed row of metal teeth	5/16

NOTE: st st = straight stream
applic = applicator

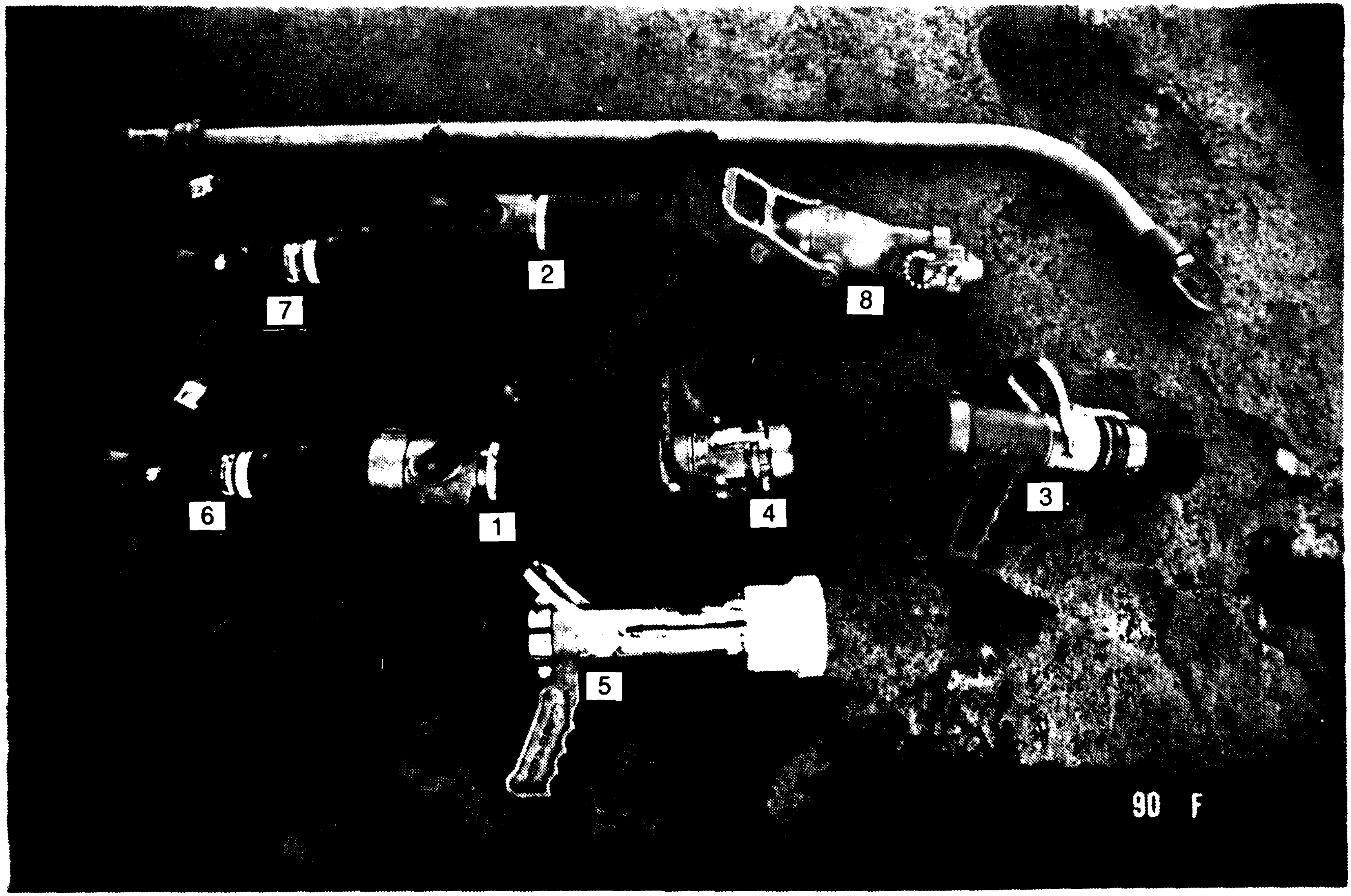


FIGURE 4. NOZZLES

Certain parameters were measured during every test. These included wind direction, wind speed, barometric pressure, and ambient temperature. Flow meters and pressure gauges were used in both the fire and the nonfire tests. A computer data acquisition system (CDAS) was used to record data from the instrumentation channels used in each test.

The water-flow measuring equipment was calibrated using a 50 gallon drum and a stopwatch. A pressure gauge was fitted in the hoseline just behind each nozzle to verify that the proper test pressure was being used.

The LPG fires used 28 thermocouples positioned at grid intersections on the portable steel frame shown in Figure 5. Three more thermocouples were placed on the LPG piping at a height of 1, 3, and 6 feet to document the severity of each tree fire. Eight calorimeters were positioned on the grid as shown in Figure 5. The water-flow and pressure were measured in each test.

Six vertical thermocouple strings were used for the compartment tests, as shown in Figure 3. One string was located at the center of the fire pen, one was adjacent to the pen and two others were placed in corners of the compartment. A string was located just inside the compartment in the doorway, and another just outside in the starboard passageway. The thermocouple heights on each string were 1,3,and 6 feet. Two strings of two thermocouples were also used in the passageway.

Calorimeters and radiometers were used in the compartment fires. Figure 3 shows their location. One string was located in the passageway by the compartment doorway and positioned to look into the compartment. One string was positioned adjacent to the weatherdeck and directed to look down the passageway in the direction of the nozzle.

4.0 RANGE/PATTERN TESTS

4.1 Procedures/Setup

Testing involved measuring the range of the straight stream and the diameters of the fog patterns as produced by the different nozzles. Figure 6 shows this type of testing. Data for the testing is shown in Appendix A. For the range measurements, a series of lines were painted two feet apart for a distance of 110 feet on the port side of the main deck of the test vessel (Figure 1). The nozzle was positioned on top of a stand three feet off the deck with an elevation angle of 30 degrees above horizontal (Figure 6). This angle provide the greatest distance at the different test pressures.

A wooden grid (16 feet wide by 16 feet high with 1 foot divisions) was erected for measuring fog pattern diameters. The nozzle was positioned behind the grid at two different distances

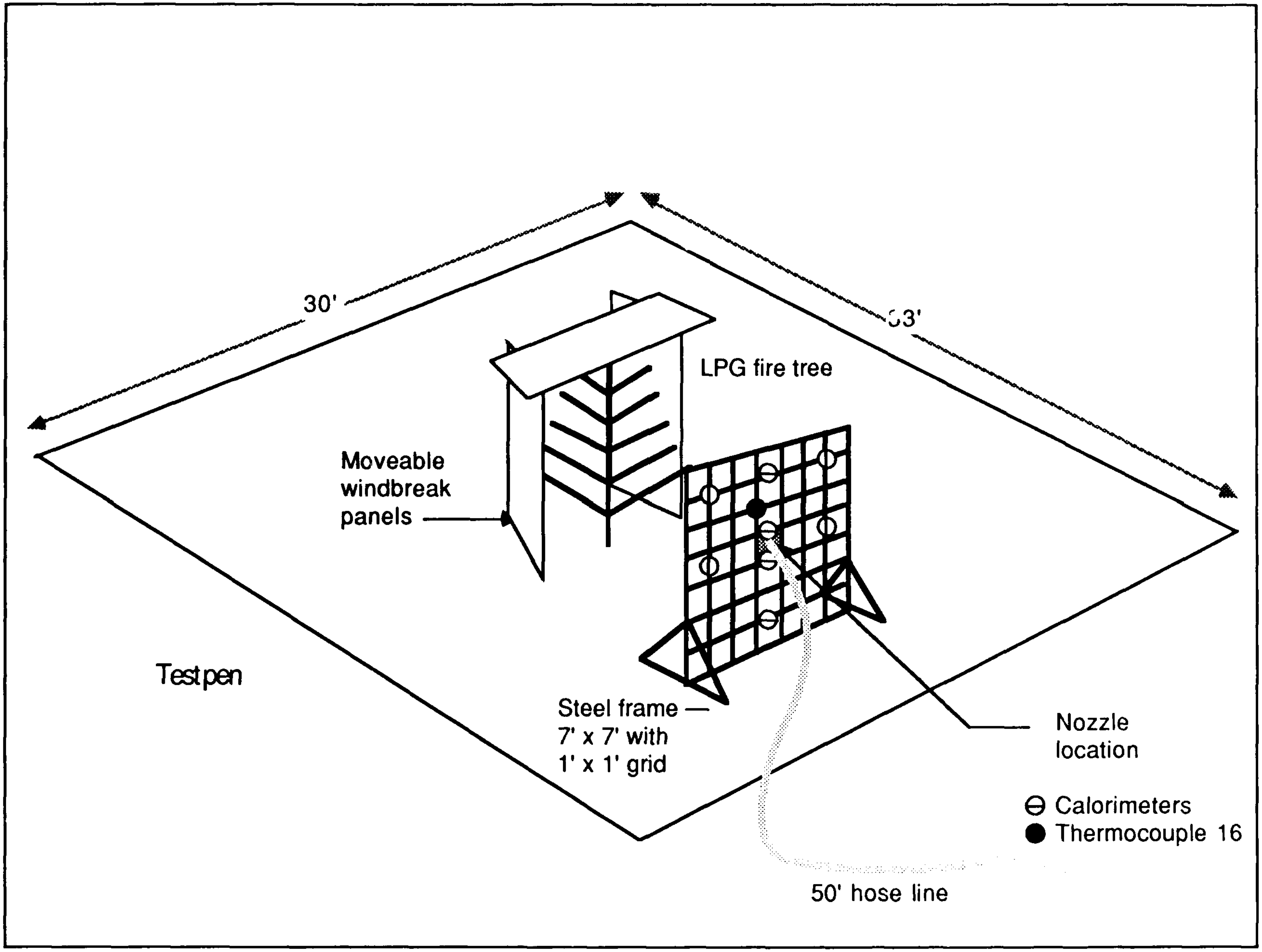
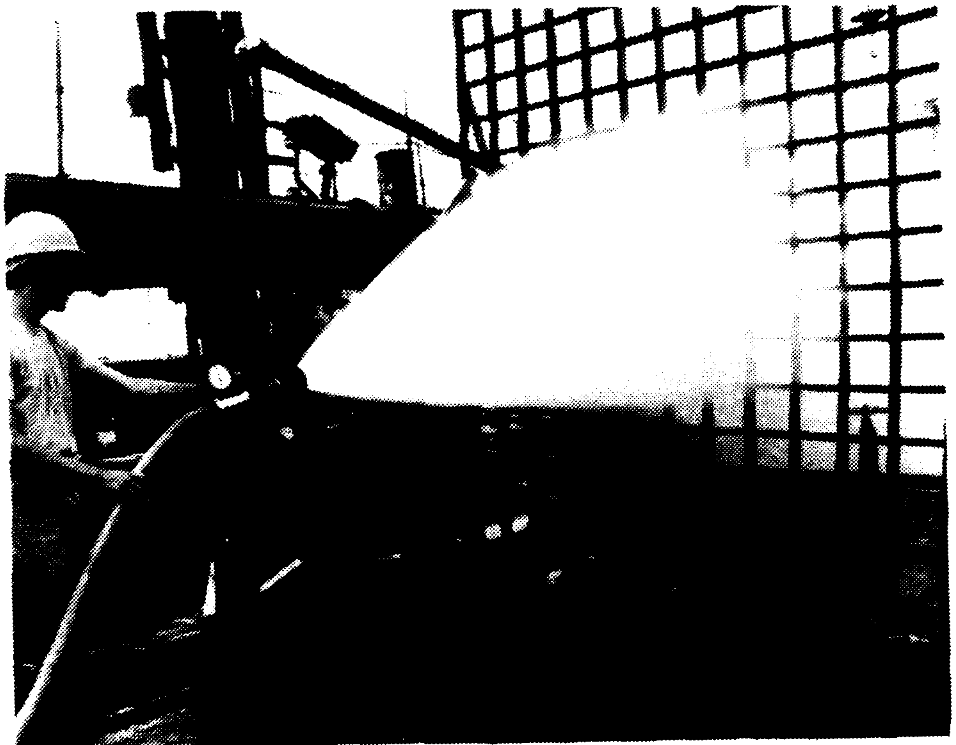


FIGURE 5. LPG INSTRUMENTATION

Range Test



Narrow Fog Pattern Test

FIGURE 6.

NONFIRE TESTING

A wooden grid (16 feet wide by 16 feet high with 1 foot divisions) was erected for measuring fog pattern diameters. The nozzle was positioned behind the grid at two different distances and at a single height so that the different fog patterns could be mapped on the grid (Figure 7). Each nozzle was positioned 3-1/2 feet off the deck and 5 feet from the grid for the wide fog pattern tests, and at the same height and 11 feet from the grid for the narrow fog pattern tests. The elevation angle for each nozzle was adjusted so that the bottom of the fog spray just touched the bottom of the wood grid. The nozzle was then clamped at this elevation angle for testing. The wide fog pattern setting marked on each nozzle was used for the wide fog pattern tests. The narrow fog pattern markings on the different nozzles produced different spray angles; therefore, a standard angle of 30 degrees was used to provide a uniform basis for comparing nozzle performance. The elevation angle of the nozzles for the narrow fog pattern was adjusted to provide the maximum diameter spray at the test distance. Each nozzle was clamped into this elevation position for the testing.

4.2 Results and Discussion

Range Tests

Twenty-one tests were conducted at operating pressures of 100, 75 and 50 psig to compare the straight stream ranges produced by the different nozzles. A pressure of 80 psig was also used in a single test for one of the automatic nozzles in order to provide a similar flow to several other nozzles. Table 2 lists the nozzles sorted in order of greatest range at the different test pressures. This data clearly shows that the commercial nozzles produced greater ranges than the Coast Guard APN at each test pressure. It is interesting to note that, even when operating at a pressure of 75 psig, the majority of the commercial nozzles produced significantly greater ranges (25 to 33%) than the Coast Guard APN operating at 100 psig. The commercial nozzles produced ranges which were 11 to 51 percent greater at 100 psig, 15 to 61 percent greater at 75 psig and 11 to 29 percent greater at 50 psig. The straight stream patterns of all the nozzles were most effective for reach and concentrated water delivery when the distance from the front to the back of the spray did not exceed six feet.

Wide Fog Patterns

Twenty tests were conducted using 4 test pressures to compare the wide fog patterns produced by the different nozzles. Most of the testing was conducted at pressures of 100, 75 and 50 psig. One automatic nozzle was tested at 80 psig in order to provide a similar flow to several other nozzles. The wide fog pattern marked on each nozzle was used in these tests (Figure 8). Table 3 lists the nozzles sorted in the order which produced the widest fog pattern at a 5 foot distance from the nozzle. Beyond this distance, the wide fog pattern appeared too thin to offer

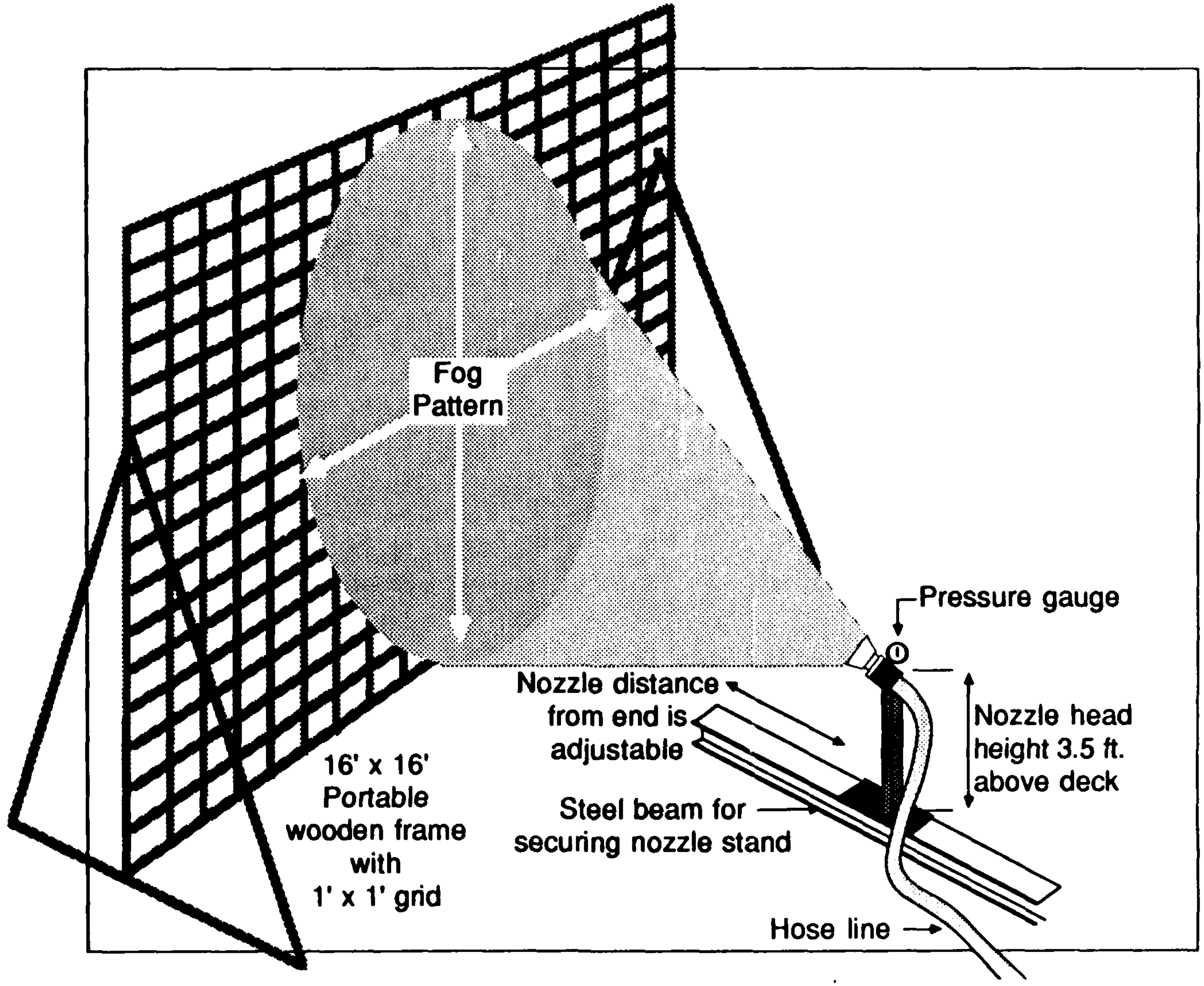
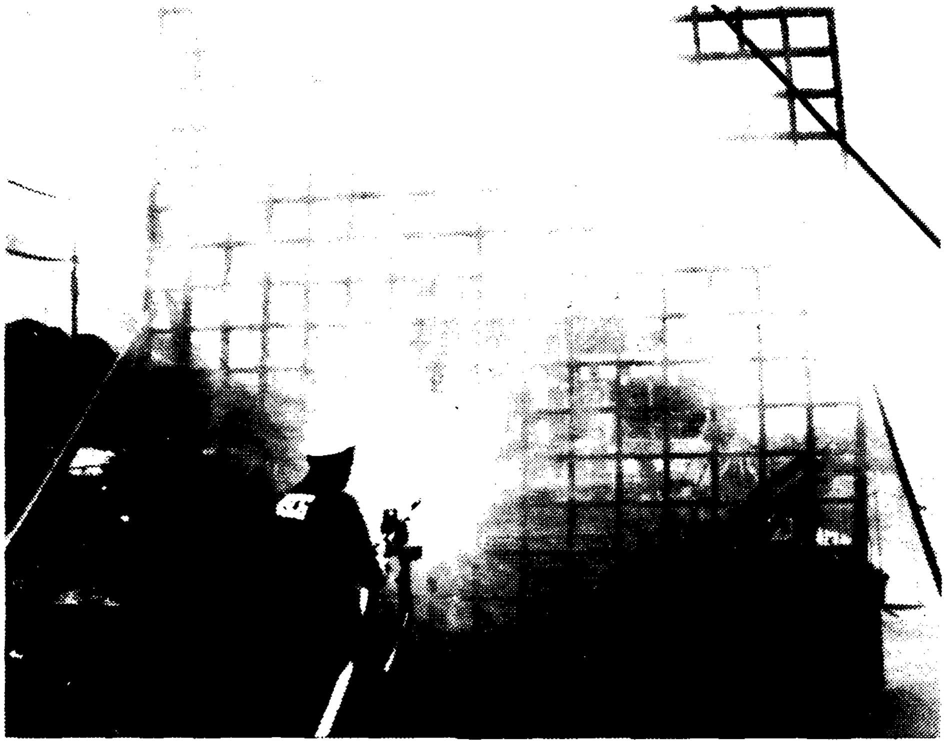


FIGURE 7. FOG PATTERN MEASUREMENTS

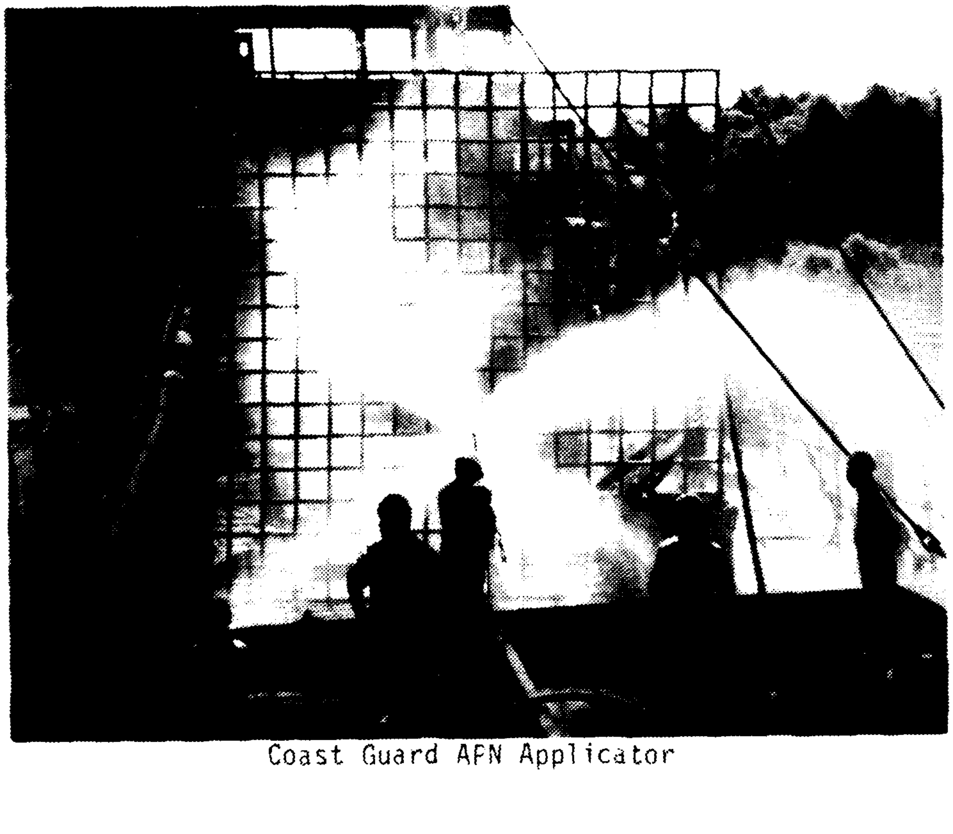
TABLE 2
DATA FOR RANGE TESTS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	Range Average (feet)
A10	AKRON 3019	100/95	100	95	st st	107
A28	ELKHART SFL-GN-95	100/95	100	95	st st	103
A60	FEECON-NAVY	100/95	100	95	st st	103
A1	AKRON 3019M	100/60	100	60	st st	79
A19	ELKHART SFL-B	100/60	100	60	st st	79
A37	CG APN	100/117	100	117	st st	71
A46	TFT BGH-125F	80/90	80	90	st st	95
A11	AKRON 3019	100/95	75	83	st st	95
A61	FEECON-NAVY	100/95	75	83	st st	95
A29	ELKHART SFL-GN-95	100/95	75	83	st st	93
A47	TFT BGH-125F	80/90	75	80	st st	89
A2	AKRON 3019M	100/60	75	52	st st	71
A20	ELKHART SFL-B	100/60	75	52	st st	68
A38	CG APN	100/117	75	99	st st	59
A12	AKRON 3019	100/95	50	68	st st	71
A30	ELKHART SFL-GN-95	100/95	50	68	st st	69
A62	FEECON-NAVY	100/95	50	68	st st	67
A3	AKRON 3019M	100/60	50	42	st st	61
A21	ELKHART SFL-B	100/60	50	42	st st	61
A48	TFT BGH-125F	80/90	50	40	st st	61
A39	CG APN	100/117	50	81	st st	55

NOTE: st st = straight stream
+ = Flow varied by plus or minus 3 gallons per minute.



Commercial Nozzle



Coast Guard APN Applicator

FIGURE 8.

WIDE FOG PATTERN TESTS

TABLE 3
DATA FOR WIDE FOG PATTERN TESTS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Average Diameter Fog Pattern at 5 feet (feet)
A59	ELKHART SM-10-FBC	105/125	75	48	16
A49	TFT BGH-125F	80/90	80	90	12
A50	TFT BGH-125F	80/90	50	40	12
A4	AKRON 3019M	100/60	100	60	11
A5	AKRON 3019M	100/60	75	52	11
A6	AKRON 3019M	100/60	50	42	11
A13	AKRON 3019	100/95	100	95	11
A14	AKRON 3019	100/95	75	83	11
A15	AKRON 3019	100/95	50	68	11
A22	ELKHART SFL-B	100/60	100	60	10
A23	ELKHART SFL-B	100/60	75	52	10
A24	ELKHART SFL-B	100/60	50	42	10
A31	ELKHART SFL-GN-95	100/95	100	95	9
A32	ELKHART SFL-GN-95	100/95	75	83	9
A33	ELKHART SFL-GN-95	100/95	50	68	9
A51	TFT BFH-95	100/95	100	95	7
A52	TFT BFH-95	100/95	75	83	7
A43	CG APN applicator	100/54	100	54	25 *
A44	CG APN applicator	100/54	75	47	22 *
A45	CG APN applicator	100/54	50	38	20 *

NOTE: * The Coast Guard applicator projected its water outward and back toward the operator.
+ = Flow varied by plus or minus 3 gallons per minute

much operator protection. In most of the commercial nozzles, a 180 degree twist of the nozzle tip could adjust the nozzles from a straight stream pattern to a wide fog pattern. The TFT nozzles and the Feecon-Navy nozzle could be adjusted from straight stream to wide fog with only a 90 degree twist of the nozzle tip. The Feecon-Navy nozzle's adjustment mechanism was almost too coarse. The wide fog pattern or narrow fog pattern of any commercial nozzle could be adjusted to numerous settings by its operator. The Coast Guard APN applicator had the widest diameter measured. Its spray was projected up, down, horizontally, and back toward the operator. None of this spray was projected toward the fire. In addition, its spray was not a solid cone of water. There were four 1 to 2 foot gaps in the spray caused by four metal prongs which projected into the flow area as shown in Figure 8.

The wide fog patterns of the commercial nozzles did vary in diameter, with the Elkhart SM-10-FBC giving the widest diameter fog pattern (16 feet) and the TFT BGH-95 nozzle giving the narrowest diameter wide fog pattern (7 feet). The narrowest wide fog pattern measured was wide enough to protect two fire fighters standing side by side while operating a nozzle. It would appear that a wide fog pattern can sometimes be too wide for operator protection and for effective control and extinguishment. More water provided for width leaves less water between the flames and the operator.

It was interesting to note that the diameter of the wide fog pattern for any specific nozzle was not reduced as the nozzle pressure was reduced. Instead, less pressure provided less reach, and a water spray which contained less volume of water. It was possible to visibly detect a reduction in the volume and or density of the water spray when operating at 50 psig, compared to that of 100 psig.

Narrow Fog Patterns

Twenty-one tests were conducted using 4 test pressures (see Table 4) to compare the narrow fog pattern diameters of the nozzles. Because of the difference in the discharge angles of the narrow fog pattern inherent to each nozzle, a standard angle of 30 degrees was used when testing each nozzle. Eleven feet was used as the distance from the nozzles to the grid used in the measurements. Table 4 indicates that half of the commercial nozzles had the same narrow fog diameter as the Coast Guard APN and that in the other cases the difference was insignificant. The different diameters is attributed to the variation in nozzle teeth design (Table 1). Because of the small difference in the diameter of the fog patterns, it is not possible to rate one nozzle ahead of the others. What is significant is that the commercial nozzles can be easily adjusted by the nozzle operator for whatever narrow fog angle is considered necessary for the situation. The Coast Guard APN on the other hand is limited to one narrow fog pattern.

TABLE 4
DATA FOR NARROW FOG PATTERN TESTS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Average Diameter Fog Pattern at 11 feet (feet)
A7	AKRON 3019M	100/60	100	60	8
A8	AKRON 3019M	100/60	75	52	8
A9	AKRON 3019M	100/60	50	42	8
A16	AKRON 3019	100/95	100	95	8
A17	AKRON 3019	100/95	75	83	8
A18	AKRON 3019	100/95	50	68	8
A25	ELKHART SFL-B	100/60	100	60	8
A26	ELKHART SFL-B	100/60	75	52	8
A27	ELKHART SFL-B	100/60	50	42	8
A34	ELKHART SFL-GN-95	100/95	100	95	8
A35	ELKHART SFL-GN-95	100/95	75	83	8
A36	ELKHART SFL-GN-95	100/95	50	68	8
A40	CG APN	100/55	100	55	8
A41	CG APN	100/55	75	47	8
A42	CG APN	100/55	50	38	8
A53	TFT BFH-125F	80/90	80	90	7
A54	TFT BFH-125F	80/90	50	40	7
A55	TFT BGH-95	100/95	100	95	7
A56	TFT BGH-95	100/95	75	83	7
A57	TFT BGH-95	100/95	50	68	7
A58	ELKHART SM-10-FBC	105/125	100	100	6

NOTE: 30 degree fog pattern used for each nozzle.
+ = Flow varied by plus or minus 3 gallons per minute

In both types of pattern tests, it was observed that for the commercial nozzles operating at a given pressure, the flow rate does not change when the spray pattern is changed from straight stream, narrow fog or wide fog. With the Coast Guard APN, when the fog pattern or the applicator is used, the flow rate is reduced by about 52 percent from the straight stream flow rate.

5.0 DEBRIS TESTS

5.1 Procedures/Setup

Two types of debris (rust and steel balls) were used to determine the effect of internal obstructions on nozzle range and patterns. Only one type of debris was used per test. The steel balls were 3/8-inch in diameter.

Rust used in the tests was collected from the deck of the test vessel. The rust was sized and stored for later use. The rust had been passed through two different size screens so that it was between 1/4-inch and 3/4-inch in size. In storing the rust, it was noted that some of it broke into pieces smaller than 1/4-inch. A small cup with graduated markings was used to measure the correct quantity for each test.

The procedure for the debris tests involved disconnecting the 1-1/2 inch hoseline at a distance of 50 feet behind the nozzle, then placing the debris into the hoseline. Water was then directed through the hoseline to the nozzle. A gauge behind the nozzle was used to verify the correct nozzle pressure. A portable flow meter (Model MF11B manufactured by Fire Research Corporation, Nesconett, NY) was placed in the fire main system to measure the flow. Flow rate was also calculated by using the nozzle pressure and flow coefficient of the nozzle.

The quantity of rust to be used for each test was selected by first passing successive quantities (2, 4, 6, 8, and then 10 fluid ounces) through the Coast Guard nozzle on its fog pattern setting at 100 psig. The purpose was to determine a quantity of debris which would just pass through the Coast Guard APN with difficulty. This quantity of debris would then be used with the commercial nozzles. Each quantity of rust was used in two different pretests to insure confidence in the results. The Coast Guard APN on wide fog pattern passed the 2, 4 and 6 fluid ounces of debris without any problem. The nozzle had considerable difficulty in passing the 8 ounces of debris but it was successful. The decision was made to use 6 fluid ounces of debris due to the extreme degree of difficulty encountered with the 8 fluid ounces.

A standard procedure was developed in attempting to clear the debris once it reached the nozzle. Once the nozzle operator recognized that the nozzle flow was affected, he was to shift the nozzle to its flush setting (largest opening) and then close and

open the nozzle bail, thereby using the water pressure as a force to clear the nozzle. The operator was to try using any combination of rotating into and out of the flush setting, opening and closing the bail, and tapping the nozzle on the deck to free the debris. The operator was given one minute to clear the nozzle of debris using the techniques described above.

5.2 Results and Discussion

Debris Tests With Rust

Sixty-two tests were conducted using rust as debris. With two exceptions, there was no significant difference between nozzles in the degree of difficulty encountered by the operator while trying to clear them of rust. The exception was two nozzles which required the use of two hands and a visual check to assure the operator that he was using the flush setting. This was dangerous, as it required the operator to divert his attention from the fire and could create a momentary loss of nozzle control in a critical situation.

Table 5 lists the nozzles in order of diminishing amounts of water passed. The most effective nozzles could be cleared to permit 100 percent of the expected water flow while the least effective nozzles permitted 0 percent flow. Table 5 also indicates that two commercial nozzles (the Akron 3019M and the Akron 3019) passed rust more effectively (6 out of 9 times and 7 out of 9 times, respectively) than the Coast Guard APN operated on its fog pattern setting (0 out of 3 times) and with its applicator (0 out of 3 times). It is interesting to note that these two commercial nozzles had smaller clearance openings, 3/16 and 5/16-inch respectively, than the Coast Guard APN (6/16-inch) and applicator (6/16-inch). The rust used in this test had been screened to be between 1/4-inch and 3/4-inch in size. It is apparent that the rust must have been reduced in size, in order to pass through the Coast Guard APN even on straight stream with its larger 5/8-inch opening and through the two commercial nozzles with the smaller flush settings listed above. One explanation is that the turbulent flow inside the hoseline caused the rust particles to hit the sides of the hose and break up. This was verified by checking the size of the rust particles before placing them into the 50 foot length of hoseline leading to the nozzle, and checking them again after removal from a nozzle which had clogged. This examination revealed that the rust had indeed been considerably reduced in size. This cannot be the complete answer, however, as this action was present in every test and every nozzle did not pass all its debris.

An internal examination of each nozzle showed that the two commercial nozzles which passed all the debris have a dual support for anchoring the nozzle stem and keeping it in the center of the barrel. This support is secured at two points 180 degrees apart inside the nozzle barrel (Figure 9). Those commercial nozzles which clogged had a support which was secured at three points (tri-support) at 120 degrees apart inside the

TABLE 5
DATA FOR DEBRIS TESTS USING RUST
(1/4 To 3/4-inch particle size)

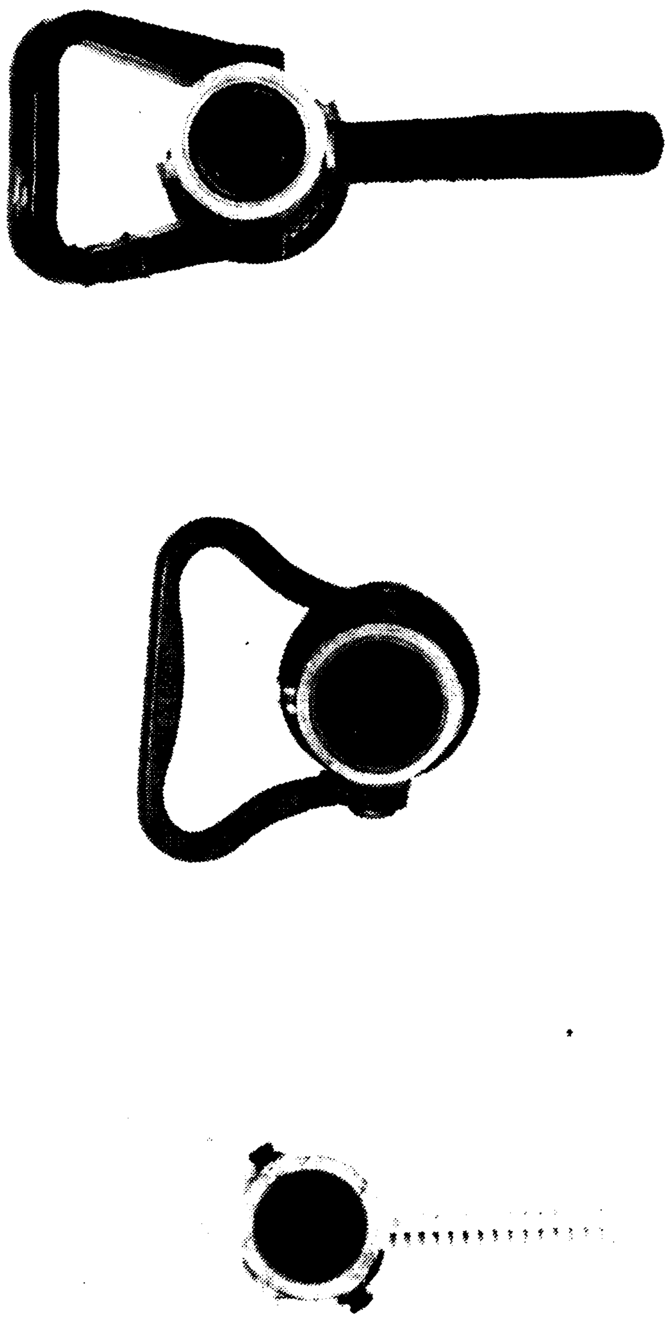
Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	Percent Test Flow Through Nozzle
A1	AKRON 3019M	100/60	100	60	st st	100
A2	AKRON 3019M	100/60	75	52	st st	100
A3	AKRON 3019M	100/60	50	42	st st	100
A4	AKRON 3019M	100/60	100	60	w/fog	100
A5	AKRON 3019M	100/60	75	52	w/fog	100
A6	AKRON 3019M	100/60	50	42	w/fog	100
A10	AKRON 3019	100/95	100	95	st st	100
A11	AKRON 3019	100/95	75	83	st st	100
A13	AKRON 3019	100/95	100	95	w/fog	100
A14	AKRON 3019	100/95	75	83	w/fog	100
A15	AKRON 3019	100/95	50	68	w/fog	100
A16	AKRON 3019	100/95	100	95	n/fog	100
A17	AKRON 3019	100/95	75	83	n/fog	100
A23	ELKHART SFL-B	100/60	75	52	w/fog	100
A28	ELKHART SFL-GN-95	100/95	100	95	st st	100
A38	CG APN	100/117	75	99	st st	100
A39	CG APN	100/117	50	81	st st	100
A40	CG APN	100/55	100	55	fog	100
A31	ELKHART SFL-GN-95	100/95	100	95	w/fog	95
A37	CG APN	100/117	100	117	st st	90
A8	AKRON 3019M	100/60	75	52	n/fog	80
A9	AKRON 3019M	100/60	50	42	n/fog	80
A27	ELKHART SFL-B	100/60	50	42	n/fog	5
A46	TFT BGH-125F	80/90	80	90	st st	5
A47	TFT BGH-125F	80/90	75	80	st st	5
A48	TFT BGH-125F	80/90	50	40	st st	5
A49	TFT BGH-125F	80/90	80	90	w/fog	5
A50	TFT BGH-125F	80/90	50	40	w/fog	5
A51	TFT BGH-95	100/95	100	95	w/fog	5
A52	TFT BGH-95	100/95	75	83	w/fog	5
A53	TFT BGH-125F	80/90	80	90	n/fog	5
A54	TFT BGH-125F	80/90	50	40	n/fog	5

NOTE: st st = straight stream
w/fog = wide fog
n/fog = narrow fog
+ = Flow varied by plus or minus 3 gallons per minute.

TABLE 5 (cont'd)
DATA FOR DEBRIS TESTS USING RUST
(1/4 To 3/4-inch particle size)

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	Percent Test Flow Through Nozzle
A7	AKRON 3019M	100/60	100	60	n/fog	0
A12	AKRON 3019	100/95	50	68	st st	0
A18	AKRON 3019	100/95	50	68	n/fog	0
A19	ELKHART SFL-B	100/60	100	60	st st	0
A20	ELKHART SFL-B	100/60	75	52	st st	0
A21	ELKHART SFL-B	100/60	50	42	st st	0
A22	ELKHART SFL-B	100/60	100	60	w/fog	0
A24	ELKHART SFL-B	100/60	50	42	w/fog	0
A25	ELKHART SFL-B	100/60	100	60	n/fog	0
A26	ELKHART SFL-B	100/60	75	52	n/fog	0
A29	ELKHART SFL-GN-95	100/95	75	83	st st	0
A30	ELKHART SFL-GN-95	100/95	50	68	st st	0
A32	ELKHART SFL-GN-95	100/95	75	83	w/fog	0
A33	ELKHART SFL-GN-95	100/95	50	68	w/fog	0
A34	ELKHART SFL-GN-95	100/95	100	95	n/fog	0
A35	ELKHART SFL-GN-95	100/95	75	83	n/fog	0
A36	ELKHART SFL-GN-95	100/95	50	68	n/fog	0
A41	CG APN	100/55	75	47	fog	0
A42	CG APN	100/55	50	38	fog	0
A43	CG APN applicator	100/54	100	54	w/fog	0
A44	CG APN applicator	100/54	75	47	w/fog	0
A45	CG APN applicator	100/54	50	38	w/fog	0
A55	TFT BGH-95	100/95	100	95	n/fog	0
A56	TFT BGH-95	100/95	75	83	n/fog	0
A57	TFT BGH-95	100/95	50	68	n/fog	0
A58	ELKHART SM-10-FBC	105/125	100	100	n/fog	0
A59	ELKHART SM-10-FBC	105/125	75	48	w/fog	0
A60	FEECON-NAVY	100/95	100	95	st st	0
A61	FEECON-NAVY	100/95	75	83	st st	0
A62	FEECON-NAVY	100/95	50	68	st st	0

NOTE: st st = straight stream
w/fog = wide fog
n/fog = narrow fog
+ = Flow varied by plus or minus 3 gallons per minute.



(Dual Support)

(Tri Support)

(Tri Support)

FIGURE 9.

INTERNAL STEM SUPPORTS FOR COMMERCIAL NOZZLES

nozzle barrel (Figure 9). One commercial nozzle had a clearance opening equal to that of the Coast Guard APN on fog and its applicator, but it also had a tri-supported nozzle stem and it clogged in every test. It was noted that the two commercial nozzles which consistently passed the rust had a flush action that could be used to (depending on the strength of the operator) literally crush the rust jammed in the nozzle tip and permit it to be discharged.

It is evident that the slightly larger clearance opening in the Coast Guard APN on fog pattern and the applicator is not the total solution for passing debris since these nozzles were clogged completely every time they were used. Making the clearance opening extremely large (e.g., 5/8-inch), as in the Coast Guard APN on straight stream) for fog patterns is also not practical since this size opening would not yield an effective fog pattern.

The above data and the fact that small rust tended to stack or pile up against the stem attachment inside the nozzles suggests that the quantity of debris is also a factor in clogging a nozzle. A flush setting of at least 3/16-inch is indeed a necessity, but flushing the fire main system periodically can help reduce the quantity of rust present inside the piping.

Debris Tests With Steel Balls (3/8-inch diameter)

Each nozzle was held 3 feet off the deck with its tip pointed down and a 3/8-inch diameter steel ball was placed into the nozzle's water inlet side. For this test the flush setting on each nozzle was used. Only the Coast Guard APN (on straight stream and on fog), its applicator and the Feecon-Navy nozzle passed the steel ball.

A second test consisted of placing fifteen 3/8-inch diameter steel balls into a hoseline connected to the nozzles and then discharging water through the hose and out each nozzle's flush setting. With one exception, each commercial nozzle was evaluated only once in this manner. This was done since the steel balls tended to become jammed inside the nozzles and it was difficult to free them without dismantling the nozzles and risking potential damage which would disrupt further testing. Table 6 shows that only the Coast Guard APN (on straight stream or fog pattern), its applicator and the Feecon-Navy nozzle was successful in passing the 3/8-inch diameter steel balls. Even in these nozzles the steel balls would sometimes jam and the operator would have to close and open the bail handle to use the force of the water to free the jam. The steel balls would then flow out.

TABLE 6
DATA FOR DEBRIS TESTS USING STEEL BALLS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	3/8 inch Steel Ball
A37	CG APN	100/117	100	117	st st	P
A38	CG APN	100/117	75	99	st st	P
A39	CG APN	100/117	50	81	st st	P
A40	CG APN	100/55	100	55	fog	P
A41	CG APN	100/55	75	47	fog	P
A42	CG APN	100/55	50	38	fog	P
A43	CG APN applicator	100/54	100	54	w/fog	P
A44	CG APN applicator	100/54	75	47	w/fog	P
A45	CG APN applicator	100/54	50	38	w/fog	P
A60	FEECON-NAVY	100/95	100	95	st st	P
A61	FEECON-NAVY	100/95	75	83	st st	P
A62	FEECON-NAVY	100/95	50	68	st st	P
A1	AKRON 3019M	100/60	100	60	st st	NP
A10	AKRON 3019	100/95	100	95	st st	NP
A19	ELKHART SFL-B	100/60	100	60	st st	NP
A28	ELKHART SFL-GN-95	100/95	100	95	st st	NP
A46	TFT BGH-125F	80/90	80	90	st st	NP
A51	TFT BGH-95	100/95	100	95	w/fog	NP
A58	ELKHART SM-10-FBC	105/125	100	100	w/fog	NP

NOTE: st st = straight stream
w/fog = wide fog
+ = Flow varied by plus or minus 3 gallons per minute.
P = Passed
NP = Not Passed

6.0 FIRE TEST PROCEDURES

The two types of fire tests conducted for this program are described in sections 6.1 and 6.2.

6.1 LPG Fires

Three scenarios were conducted with the LPG fire setup to determine the protection provided to the nozzle operator by the different nozzles. Twenty-four fire tests were conducted to determine the protection provided to the operator by the wide fog patterns of the different nozzles. Three additional wide fog pattern fire tests were conducted with a 3 percent AFFF solution to determine whether a foam spray provided greater heat protection than water alone. In addition, six more fire tests were conducted to investigate the differences in protection provided by the narrow fog patterns of the nozzles.

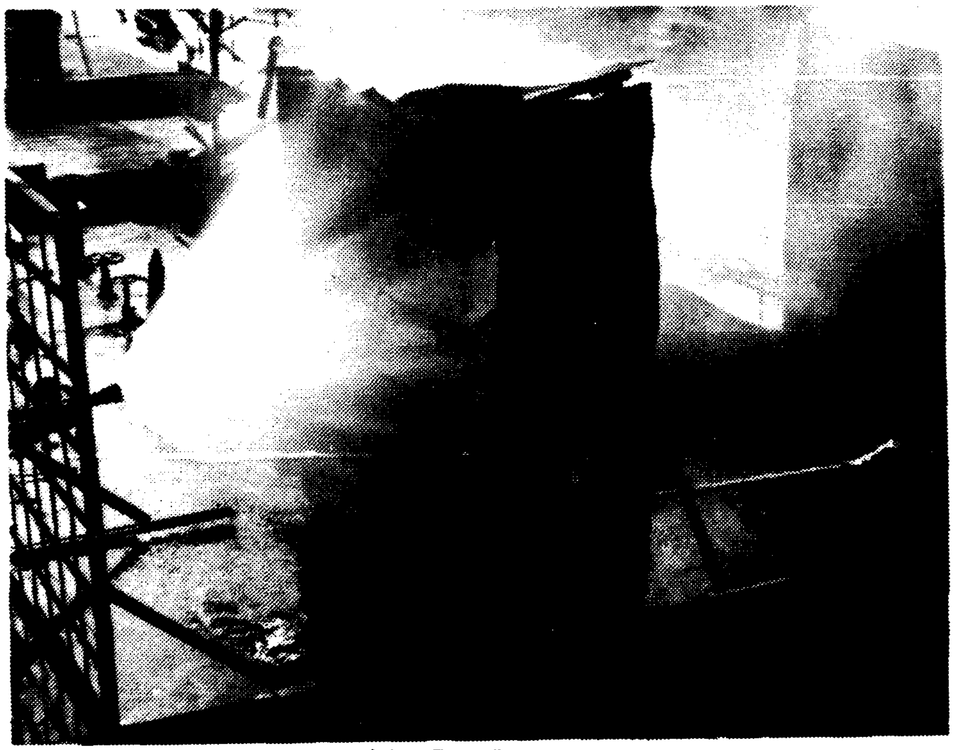
A piping "tree" for the LPG fires was located in the aft test pen on the starboard side of the main deck. The piping is shown in Figure 4. The LPG fires were conducted using commercial grade propane. The propane was stored in large tanks and channeled to the piping "tree" where it was burned. The propane for each fire was regulated by a valve which was a remote distance from the fire.

A steel grid 7 feet high by 7 feet wide with 1 foot subdivisions was constructed to hold test instrumentation (Figure 5) behind the fog pattern produced by each nozzle. For each test, the nozzle was clamped 3-1/2 feet above the deck and pushed through the frame for a distance of 1 foot. The nozzle was positioned 4 feet away from the tree for the wide fog pattern tests (Figure 10). This distance provided a measurable heat flux and constant high temperatures. The nozzle was positioned 8 feet away from the tree for the narrow fog pattern tests (Figure 10). Beyond this distance the heat flux became too low for effective measurement and comparison.

The wide fog pattern setting used for each nozzle was that marked on its instructions. The narrow fog pattern used for each nozzle was set at 30 degrees to eliminate a variable from the testing. Both fog patterns were adjusted so that the curtains just touched the ground in front of the LPG fire (to prevent flames from sweeping in under the spray and thus endangering the imaginary nozzle operator). This was performed by adjusting the elevation angle of each nozzle and then clamping it at the same height for each test.

Data was recorded in each nozzle test for two situations, an operator unprotected (no water spray) and then protected by a water spray. For each test, the fire was started and allowed to burn until the thermocouples indicated a constant high temperature. Thermocouple 16 was used to gauge this as it was

Narrow Fog Pattern



Wide Fog Pattern

FIGURE 10.

LPG FIRES - COMMERCIAL NOZZLES

located five feet high and just above the left shoulder of the imaginary nozzle operator. The temperature at this location leveled off at approximately 3:25 (minutes:seconds) test time in the range of 250 to 275 degrees C. Water was then sprayed through the nozzle for 12 minutes. Prior to the application of water through the nozzle, it was covered by a protective heat reflective material which was removed by the force of the water spray. All temperatures and heat flux readings were recorded. The schedule for the thirty-three tests is listed in Appendix B.

6.2 Compartment Fires

The fire test compartment was located on the starboard side of the 01 deck of the test vessel. A floor plan of the compartment is shown in Figure 3. All combustibles were removed from the compartment except for the Class B fuel load used in each test. A steel pen 4 x 4 x 1/2 foot was placed in the center of the compartment and used for the burn pen. Ten gallons of marine diesel fuel and one gallon of mineral spirits were added for each fire test. The instrumentation is described in section 3.3.

Pretests

Five pre-tests were conducted to determine and define the correct firefighting techniques to be used in attacking the compartment fires. The pre-tests were also used to check the data acquisition system and insure that it was working properly. One commercial nozzle and the Coast Guard APN were used in the pre-tests.

Two basic items, protective firefighting gear and the position of a door near the end of the passageway, were varied during the pretests. The three combinations of protective firefighting gear are listed below:

a. Helmet with face shield, flashhood, Scott "Air Pack", fireman's turnout coat and pants, knee high fireman's boots, and heavy duty leather gloves.

b. Helmet with face shield, flashhood, Scott "Air Pack", Nomex coveralls, knee-high fireman's boots and heavy duty leather gloves.

c. Helmet with face shield, flashhood, Scott "Air Pack", Nomex coveralls, a rain jacket, knee-high fireman's boots and heavy duty leather gloves.

During each pretest, the temperatures were monitored inside the compartment to determine when peak conditions had been established so that extinguishment procedures could begin. Typically at test time 3:45 (minutes:seconds) the overall temperatures at a six foot height adjacent to the fire pen had reached a constant temperature of 650 degrees C. At this time

the nozzle operator began extinguishment procedures. The nozzle operator entered the starboard passageway, proceeded to the compartment doorway and sprayed water on the fire. Extinguishment time was the period starting when the operator entered the passageway and ending when all fire in the test pen was out. During the pretests different techniques were tried in the application of water. For example, either the firefighter began cooling down the passageway as he entered it or he instead stayed very low, advanced in the passageway to the compartment doorway and then applied water. The results of the pretests indicated that a different firefighting method had to be used in the actual tests.

Stationary Nozzle

The safety of the firefighters made it necessary to use a different firefighting method in the actual tests. In the new method, each nozzle was permanently secured for its test on a 2-1/2 foot stand in the passageway and was pointed into the compartment. This method eliminated exposing the firefighter to the severe conditions (smoke, heat and steam) in the passageway. The water was applied from each fixed nozzle in a narrow fog pattern for four minutes to evaluate the capabilities for extinguishing the fire and cooling the compartment area.

Thirty tests were conducted. The nozzles and pressure/flow combinations are listed in Appendix C. The nozzles were tested at pressures of 50 and 75 psig. Extinguishment time was from the point of water application till the fire in the test pen was out. The cameras and the test instrumentation were used to determine when the fire was extinguished.

7.0 NOZZLE EFFECTIVENESS

The results in the following sections are based on tests conducted for this project and two nozzle test programs conducted earlier by the Coast Guard at its Fire and Safety Test Detachment.

7.1 Nozzle Characteristics

The following characteristics reflect the comments of the nozzle operators based on their previous experience and the results of their hands-on experience during this test series. Nozzle manufacturers' representatives were asked for their comments and their answers were considered in light of the nozzle operators suggestions.

Based on these comments and suggestions, a 1-1/2 inch nozzle should extinguish and control Class A and B fires aboard ships without the use of attachments. The nozzle should weigh no more than ten pounds and be capable of producing both straight stream and adjustable spray patterns. It should be constructed of

bronze or brass and its stationary and moving parts should be designed for inherent resistance to shock, marine corrosion, heat and flames. The nozzle should have a pistol grip handle on its underside. Flow through the nozzle should be controlled by a ball-valve.

The nozzle should be capable of producing an adjustable fog pattern by means of an impinging action by one (or a maximum of two) fixed concentric row of teeth around the discharge orifice. Spinning teeth provide a cone pattern which appears more solid but at the same time they are prone to jam. In addition, the spinning teeth tend to reduce the water being projected directly in front of the nozzle to keep flames away from the operator. The fog pattern should be adjustable from straight stream to narrow angle fog (30 degrees) to wide angle fog (90 degrees minimum) to flush position. The flush opening should have a minimum diameter of 3/16-inch. The flush setting should be easily operable with the use of one hand while the operator's other hand is located on the pistol grip of the nozzle. The fog pattern shall be a full cone with no gaps in the pattern. The pattern adjustment should be such that not more than 180 degrees of counterclockwise rotation is required for the full range of adjustment from straight stream to wide angle fog. Rotation of more than 180 degrees requires unnecessary repeditive hand movements by the nozzle operator. Rotation of less than 180 degrees (i.e., 90 degrees) provides too rapid a shift from one pattern to the other with the potential of placing the nozzle in a pattern which isn't desired, thereby creating a potentially dangerous situation for the operator. Each of the pattern positions shall have a detent and symbol representation of the pattern position to provide positive indications for the operator. The symbol representation of the pattern position should be constructed such that it will not rub off or fade out after frequent use.

A 1-1/2 inch nozzle should be capable of providing a flow of 95 gpm at 100 psig. Its range at this pressure should be at least 105 feet (+/-5%). The coupling threads for the nozzle should be American National Standard Fire-Hose Threads with 9 threads per inch for the 1-1/2 inch hose line.

7.2 Operator Protection

7.2.1 LPG Fires

General

A literature search was conducted to determine heat flux levels which produce physiological effects on the firefighter. Figure 11 (data taken directly from Reference 15) shows the tolerance of exposed human tissue to incident heat flux. This figure also shows that the heat flux levels (2-3 Btu/sq ft/sec) during the unprotected segments of the LPG tests would have been

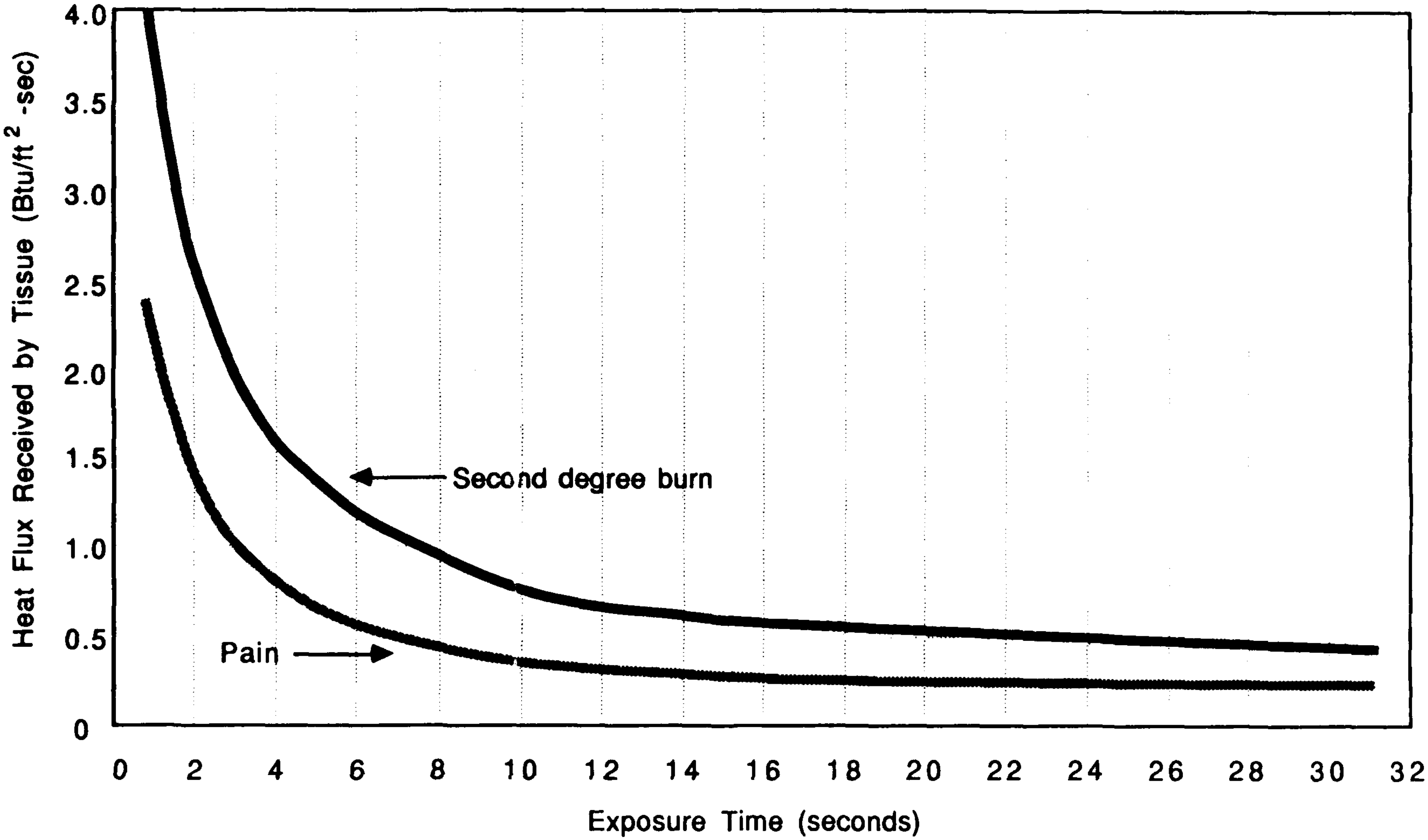


FIGURE 11. HUMAN TISSUE TOLERANCE TO HEAT

sufficient to create 2nd degree burns in 2-3 seconds on unprotected human tissue. Heat flux was thus selected as the comparison factor used to rank and compare nozzle performance in the LPG fires. The heat flux was also found to be very consistent for the unprotected segment of each fire test.

An examination of the thermocouple data indicated that during the LPG fires the temperatures experienced by an unprotected operator would have ranged from 149 to 190 degrees Celsius. When protected these values would have been reduced and ranged from 40 to 100 degrees Celsius.

Table 7 is a complete listing of heat flux reduction test results arranged by the mode of nozzle operation: wide fog pattern, narrow fog pattern, and wide fog pattern with AFFF. Within each of these modes, the nozzles are listed in descending order of the reduction of heat flux achieved while operating at or near the manufacturers rated pressure/flow conditions. This heat flux percentage was determined by first averaging the area under the curve for 4 calorimeters when the operator was unprotected for 3 minutes. This value was divided by the average of the area under the curve for the same 4 calorimeters for a 6 minute period when the operator was protected by the nozzle's spray. The percent heat flux reduction for the nozzle at each flow rate and pressure is 100 times the quantity 1.0 minus the quotient of the protected average heat flux divided by the unprotected average heat flux. Note that the greatest flow (highest pressure) through an individual nozzle produces the greatest heat reduction and therefore, the best protection for the nozzle operator.

The date in Table 7 indicates that the best level of operator protection (95 to 98 percent reduction of heat flux) was provided by four commerical nozzles operating at a high pressure (100 psig). Three of these nozzles have a rated flow of 95 gpm at 100 psig. The other has a rated flow of only 60 gpm at this pressure, yet it still achieved a heat flux reduction of 95 percent. This indicates that design as well as flow is required to provide operator protection. Also, the commercial nozzles on wide fog patterns provided heat flux reductions of between 70 and 98 percent, whereas the Coast Guard APN and or its applicator produced heat flux reductions of 60 to 74 percent. This indicates that the commercial nozzles provided 21 percent greater heat flux reduction at similar low flow rates (38-40 gpm), 29 percent greater heat flux reduction at similar medium flow rates (47-52 gpm) and 24 percent greater heat flux reduction at high flow rates of 95 gpm. This illustrates the advantage of the commercial nozzles over the Coast Guard APN and/or applicator in providing greater operator protection even when operating at lesser flow rates.

The data in Table 7 also indicates that the commercial nozzles provide protection equivalent to that of the Coast Guard APN when using the same narrow fog pattern of 30 degrees and

TABLE 7
HEAT FLUX REDUCTION PER NOZZLE AT DIFFERENT FLOW/PRESSURES

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	Heat Flux (BTU/sqft /sec) Unprotected Operator	Heat Flux (BTU/sqft /sec) Protected Operator	Heat Flux Reduction Achieved by Nozzle Spray (%)	
WIDE FOG PATTERN - Nozzle Positioned 4 feet from tree									
B11	AKRON 3019	100/95	100	95	w/fog	2.4	0.1	98	
B23	AKRON 3019	100/95	75	83	w/fog	2.6	0.2	92	
B4	AKRON 3019	100/95	50	68	w/fog	2.1	0.3	86	
B35	FEECON-NAVY	100/95	100	95	w/fog	2.4	0.1	96	
B36	FEECON-NAVY	100/95	50	68	w/fog	2.5	0.3	88	
B19	ELKHART SFL-B	100/60	100	60	w/fog	2.0	0.1	95	
B22	ELKHART SFL-B	100/60	75	52	w/fog	2.2	0.2	91	
B12	ELKHART SFL-B	100/60	50	42	w/fog	2.5	0.5	80	
B31	TFT BGH-95	100/95	100	95	w/fog	2.1	0.1	95	
B26	AKRON 3019M	100/60	100	60	w/fog	2.0	0.2	90	
B5	AKRON 3019M	100/60	75	52	w/fog	3.2	0.4	88	
B14	AKRON 3019M	100/60	50	42	w/fog	2.2	0.4	82	
B10	ELKHART SFL-GN-95	100/95	100	95	w/fog	2.2	0.3	86	
B16	ELKHART SFL-GN-95	100/95	75	83	w/fog	2.3	0.0	83	
B9	ELKHART SFL-GN-95	100/95	50	68	w/fog	2.7	0.5	81	
B32	TFT BGH-125F	80/90	75	80	w/fog	2.0	0.3	85	
B33	TFT BGH-125F	80/90	50	40	w/fog	2.1	0.4	81	
B2	CG APN	100/55	100	55	**	2.3	0.6	74	
B20	CG APN	100/55	75	47	**	2.2	0.6	73	
B18	CG APN	100/55	50	38	**	2.4	0.1	67	
B34	ELKHART SM-10-FBC	105/125	75	48	w/fog	2.0	0.6	70	
B15	CG APN applicator	100/54	100	54	w/fog	2.5	0.9	64	
B8	CG APN applicator	100/54	75	47	w/fog	2.4	0.9	62	
B1	CG APN applicator	100/54	50	38	w/fog	2.0	0.8	60	

NARROW FOG PATTERN - Nozzle positioned 8 feet from tree									
B28	AKRON 3019M	100/60	75	52	n/fog	2.1	0.5	76	
B29	FEECON-NAVY	100/95	75	83	n/fog	1.6	0.4	75	
B30	CG APN	100/55	75	47	**	1.5	0.4	73	
B7	TFT BGH-60	100/60	75	52	n/fog	1.8	0.5	72	
B3	ELKHART SFL-B	100/60	75	52	n/fog	1.4	0.4	71	
B17	CG APN	100/55	50	38	**	1.7	0.5	71	

WIDE FOG PATTERN WITH AFFF - Nozzle positioned 4 feet from tree									
B37	AKRON 3019M	100/60	75	52	w/fog	2.2	0.2	91	3.00% AFFF
B38	TFT BFH-60	100/60	75	52	w/fog	2.4	0.3	88	3.25% AFFF
B39	ELKHART SFL-B	100/60	75	52	w/fog	2.5	0.4	84	2.75% AFFF

NOTE: w/fog = wide fog
n/fog = narrow fog
+ = flow varied by plus or minus 3 gallons per minute
** = fog pattern same as commerical narrow fog

similar flow rates. Further, it shows that the use of a 3% AFFF solution with the commercial nozzles does not increase the protection to the nozzle operator over that provided by water spray when equivalent flow rates and pressures are used.

Specifics

Table 7 indicates that five commercial nozzles (Akron 3019, Feecon-Navy, TFT BGH-95, Elkhart SFL-B, and the Akron 3019M) reduced the heat flux to the the operator by 90 percent or better when operated on their wide fog settings. Each of these nozzles has a fixed flow rate at a design specified operating pressure. The test flow rates (which achieved 90 percent or better heat flux reduction) varied from 52 to 95 gpm for these nozzles. This indicates that nozzle design characteristics as well as flow rate have an effect on the capabilities of the nozzle to provide operator protection.

The Akron 3019M and the Akron 3019 are identical nozzles, except for the orifice size which produces different flow rates. When we compare the heat flux reduction for these two nozzles at the three test pressures for the wide fog tests (Table 7), we see that the higher flow nozzle provides a greater percentage of heat reduction when compared at identical pressures. This demonstrated what one would expect, more water through the same nozzle will provide greater operator protection.

The Elkhart SFL-B nozzle had spinning teeth, whereas the Elkhart SFL-GN-95 nozzle has a single row of short fixed brass teeth. If we compare the percent of heat reduction between these nozzles in Table 7 we find that the SFL-B nozzle with the spinning teeth provides a slightly greater heat reduction, up to 9 percentage points at 100 psig, although it was operating at approximately 35 gpm less flow at this test pressure. This indicates that the nozzle design compensated for the difference of the additional flow to provide greater operator protection. The data in Table 7 also indicates that the SFL-GN-95, when operating at 100 psig pressure, provided lower heat flux reduction (by 9 to 12 percentage points) than fixed flow rate commercial nozzles with identical flow/pressure design characteristics. Thus design as well as flow is important to effectiveness for operator protection.

Two automatic nozzles (TFT BGH-125F, Elkhart SM-10-FBC) were evaluated at selected pressures in the wide fog pattern mode. Neither of the automatics outperformed commercial nozzles with fixed flow rates when operating at similar flows, but one automatic (TFT) performed as well as equivalent fixed flow rate nozzles at the same flow rate. The performance of the second automatic (Elkhart SM-10-FBC) nozzle was similar to that of the Coast Guard APN.

Although not designed specifically for marine use, the TFT nozzles offered a few unique features which warranted their

inclusion in the testing. They featured a debris screen built into the inlet side of the nozzle to trap debris too big to flush through the nozzle. Its fog pattern mechanism consists of a single row of rectangular teeth instead of the conventional circular teeth. When compared to the other commercial nozzles, the TFT automatic and TFT fixed nozzles offer degrees of protection which were comparable to the other nozzles at equivalent flow/pressure values.

Of all the nozzles tested, the Coast Guard applicator (Figure 12) provided the lowest degree of heat flux protection to the operator. At its lowest test flow it provided 10 percentage points less heat flux protection than the poorest of the commercial nozzles. When operating at its highest test flow it provided 6 percentage points less heat flux protection than the poorest of the commercial nozzles. This percentage would increase to 34 percentage points if the commercial nozzles with the highest flow rates were considered. It is interesting to note that the applicator provided less heat flux protection (7 percentage points at its lowest flow and 10 percentage points at its highest flow) than the Coast Guard APN on its fog pattern.

7.2.2 Compartment Fires

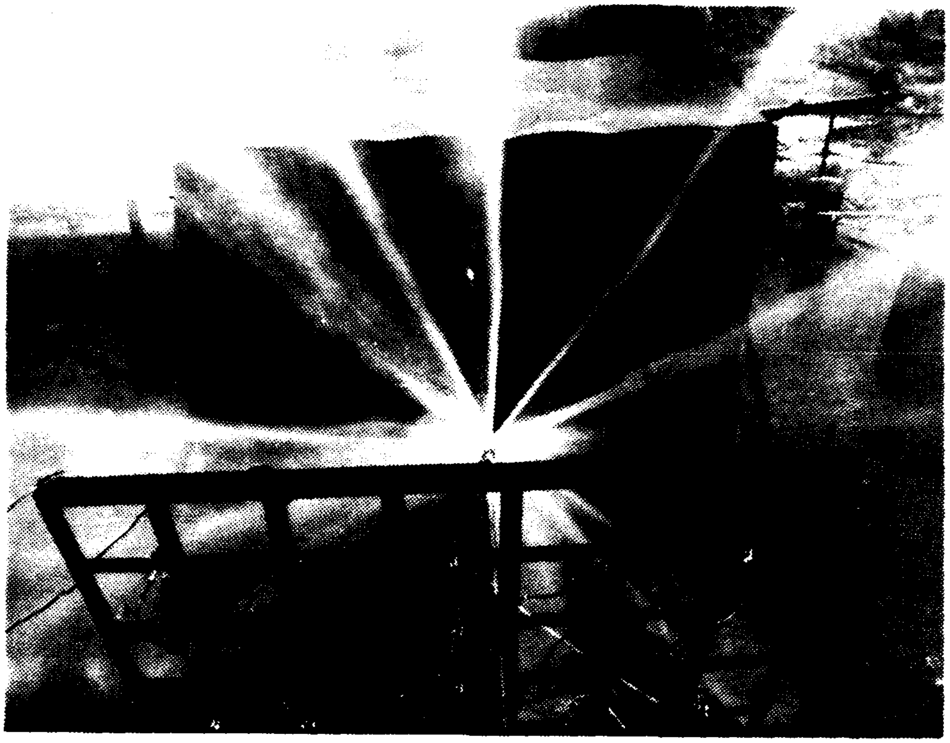
Pretests

It was found that with any combination of firefighting gear and either test nozzle, the operator could get to the fire quite easily, provided that there was an outlet (such as an open doorway leading to a passageway or a large adjacent compartment nearby) so that the water spray could be used to push away the smoke, heat and steam (produced by water application). If an outlet did not exist for venting, the best approach was to stay low and advance to the fire while using as little water as possible. The application of too much water creates sufficient steam, that without an outlet for venting, the firefighter would have to withdraw regardless of which protective clothing was worn or which nozzle was used.

Stationary Nozzle Tests

The lack of a firefighter at the nozzle made it necessary to examine the capabilities of the nozzles in reducing compartment temperatures for operator protection and habitability.

Table 8 lists the nozzles in descending order which produced the greatest temperature reduction in the compartment at the end of four minutes of water application. The temperatures listed in this table are a result of combining and averaging temperatures recorded at six different locations in the compartment. Three of the locations were at a 6 foot height and three were at a 3 foot height in three corners of the compartment. The range in percent of temperature reduction between the hightest ranked nozzle and the lowest ranked nozzle (not including test #16) is 9 percentage points. This range is not sufficient for determining the exact



Pattern - No Flames

Pattern - With Flames

FIGURE 12.

LPG FIRES - COAST GUARD APN APPLICATOR

TABLE 8
NOZZLE RANKING BY REDUCING COMPARTMENT TEMPERATURE

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	Compt. Temp. before Water (deg C)	Compt. Temp. after Water (deg C)	% Reduction	Exting. Time (sec.)
C2	TFT BGH-125F	80/90	75	80	n/fog	480	79	84	<20
C17	ELKHART SFL-GN-95	100/95	75	83	n/fog	477	80	83	<20
C7	CG APN	100/55	75	47	fog	492	85	83	<20
C8	CG APN applicator	100/54	75	47	w/fog	501	87	83	<20
C31	ELKHART SFL-GN-95	100/95	75	83	n/fog	482	89	82	<20
C34	CG APN	100/55	75	47	fog	493	91	82	<20
C22	CG APN applicator	100/54	50	38	w/fog	498	88	82	<20
C35	AKRON 3019M	100/60	75	52	n/fog	490	92	81	<20
C30	AKRON 3019M	100/60	75	52	n/fog	494	95	81	<20
C26	AKRON 3019	100/95	75	83	n/fog	494	95	81	<20
C12	CG APN	100/55	50	38	fog	491	94	81	<20
C24	CG APN applicator	100/54	50	38	w/fog	511	99	81	<20
C36	AKRON 3019M	100/60	50	42	n/fog	496	102	80	<20
C18	ELKHART SFL-GN-95	100/95	50	68	n/fog	473	92	80	<20
C21	ELKHART SFL-GN-95	100/95	50	68	n/fog	485	97	80	<20
C4	TFT BGH-95	100/95	75	83	n/fog	484	98	80	<20
C6	FEECON-NAVY	100/95	75	83	n/fog	487	96	80	<20
C25	ELKHART SFL-B	100/60	75	52	n/fog	482	99	79	<20
C32	CG APN	100/55	50	38	fog	481	100	79	<20
C5	FEECON-NAVY	100/95	50	68	n/fog	479	102	79	<20
C14	AKRON 3019M	100/60	50	42	n/fog	514	112	78	<20
C27	AKRON 3019	100/95	50	68	n/fog	513	114	78	<20
C15	AKRON 3019	100/95	75	83	n/fog	522	113	78	<20
C33	ELKHART SFL-B	100/60	75	52	n/fog	523	113	78	<20
C28	ELKHART SFL-B	100/60	50	42	n/fog	489	114	77	<20
C23	ELKHART SFL-B	100/60	50	42	n/fog	487	114	77	<20
C3	TFT BGH-95	100/95	50	68	n/fog	491	113	77	<20
C11	AKRON 3019	100/95	50	68	n/fog	482	120	75	<20
C1	TFT BGH-125F	80/90	50	40	n/fog	465	114	75	<20
C16	CG APN applicator	100/54	75	47	w/fog	502	190	62 *	<20

NOTE: n/fog = narrow fog
w/fog = wide fog
* = Compartment temperature was sufficient to expand the pressure fitting on the end of the applicator so that the tip came off resulting in a solid straight stream. Applicator tip was modified to prevent reoccurrence in remaining tests.
\+ = Flow varied plus or minus 3 gallons per minute.

nozzle ranking order for capability in temperature reduction for operator protection. This data also does not indicate any nozzle to be clearly superior in reducing the compartment temperatures. The diversity of the nozzles in this ranking does indicate, however, that the commercial nozzles were equivalent to the Coast Guard APN and applicator for reducing compartment temperatures.

It is interesting to note in Table 8 that a straight stream (produced in test #16 when the deflector tip separated and fell off) will extinguish the fire in the same time, but it will not reduce the room temperatures to the same degree, or as quickly, as the fog patterns.

Table 9 lists the percent temperature reduction for each nozzle in the compartment tests. A check of the percent reduction column indicates that all nozzles, with the exception of one test, were similar in reducing compartment temperatures within a range of 9 percentage points. This limited range, and the diversity of the nozzles throughout this range, does not indicate any one nozzle to be superior to the others. The extinguishment data and the temperature cooling data both indicate that the commercial nozzles were equivalent to the Coast Guard APN and applicator.

Table 9 also shows a certain characteristic which holds true for each nozzle. That is, when the flow increases slightly, the temperature in the compartment is slightly reduced. The flow increase for most nozzles ranged from 9 to 15 gpm and this only affected the percent compartment temperature reduction slightly (6 percent). In one test however, the flow increase to the nozzle (test C1 vs C2) was 40 gpm. In this case, the greatest percent temperature reduction (9 percent) was observed. This indicates that large quantities of water are needed for cooling purposes, whereas earlier we found that a limited quantity of water is sufficient for extinguishment.

7.3 Firefighting

The following two sections discuss nozzle effectiveness for the control and extinguishment of deck fires and compartment fires. The discussion will include the results of both commercial and Coast Guard test programs.

7.3.1 Deck Fires

At least two fire test programs, in addition to this one, have been conducted (one by Texas A&M University in November 1985 and one by Exxon Marine Research in March 1986) which clearly indicate that commercial nozzles provide a substantial advantage over the Coast Guard APN in controlling and extinguishing Class B fires when using water. Final reports have yet to be published concerning these programs, but the results were made available for this project. The firefighters in these organizations also stated that they preferred the commercial nozzles based on its performance during their testing and in their firefighting training.

TABLE 9
PERCENT COMPARTMENT TEMPERATURE REDUCTION BY NOZZLES

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Flow+ (gpm)	Pattern	Compt. Temp. before Water (deg C)	Compt. Temp. after Water (deg C)	% Reduction	Exting. Time (sec.)
C36	AKRON 3019M	100/60	50	42	n/fog	496	102	80	<20
C14	AKRON 3019M	100/60	50	42	n/fog	514	112	78	<20
C35	AKRON 3019M	100/60	75	52	n/fog	490	92	81	<20
C30	AKRON 3019M	100/60	75	52	n/fog	494	95	81	<20
C27	AKRON 3019	100/95	50	68	n/fog	513	114	78	<20
C11	AKRON 3019	100/95	50	68	n/fog	482	120	75	<20
C15	AKRON 3019	100/95	75	83	n/fog	522	113	78	<20
C26	AKRON 3019	100/95	75	83	n/fog	494	95	81	<20
C28	ELKHART SFL-B	100/60	50	42	n/fog	489	114	77	<20
C23	ELKHART SFL-B	100/60	50	42	n/fog	487	114	77	<20
C33	ELKHART SFL-B	100/60	75	52	n/fog	523	113	78	<20
C25	ELKHART SFL-B	100/60	75	52	n/fog	482	99	79	<20
C18	ELKHART SFL-GN-95	100/95	50	68	n/fog	473	92	80	<20
C21	ELKHART SFL-GN-95	100/95	50	68	n/fog	485	97	80	<20
C31	ELKHART SFL-GN-95	100/95	75	83	n/fog	482	89	82	<20
C17	ELKHART SFL-GN-95	100/95	75	83	fog	477	80	83	<20
C32	CG APN	100/55	50	38	fog	481	100	79	<20
C12	CG APN	100/55	50	38	fog	491	94	81	<20
C7	CG APN	100/55	75	47	fog	492	85	83	<20
C34	CG APN	100/55	75	47	fog	493	91	82	<20
C22	CG APN applicator	100/54	50	38	w/fog	498	88	82	<20
C24	CG APN applicator	100/54	50	38	w/fog	511	99	81	<20
C16	CG APN applicator	100/54	75	47	w/fog	502	190	62 *	<20
C8	CG APN applicator	100/54	75	47	w/fog	501	87	83	<20
C1	TFT BGH-125F	80/90	50	40	n/fog	465	114	75	<20
C2	TFT BGH-125F	80/90	75	80	n/fog	480	79	84	<20
C3	TFT BGH-95	100/95	50	68	n/fog	491	113	77	<20
C4	TFT BGH-95	100/95	75	53	n/fog	484	98	80	<20
C5	FEECON-NAVY	100/95	50	68	n/fog	479	102	79	<20
C6	FEECON-NAVY	100/95	75	83	n/fog	487	96	80	<20

NOTE: n/fog = narrow fog
w/fog = wide fog
* = Compartment temperature was sufficient to expand the pressure fitting on the end of the applicator so that the tip came off resulting in a solid straight stream. Applicator tip was modified to prevent reoccurrence in remaining tests.
+ = Flow varied plus or minus 3 gallons per minute.

The above results support the findings of two test programs previously conducted by the Coast Guard (References 1, 2) which show that commercial nozzles using 3 and 6 percent AFFF solutions clearly provide a substantial advantage over the Coast Guard approved nozzles in controlling and extinguishing Class B fires. To date, a test program comparing commercial nozzles and nozzles approved by the Coast Guard for use with AFFF onboard merchant vessels for combating Class B deck fires has not been conducted.

7.3.2 Compartment Fires

Pretests

The pretests indicated that control and extinguishment would take place in 20 seconds or less, once the nozzle operator was able to reach the doorway and spray water on the fire. The small size (16 square feet) of the fire, its type (Class B), and its location obviously affected the control and extinguishment times, but the pretests did indicate that a commercial nozzle was as effective as the Coast Guard APN in control and extinguishment of the compartment fires. If the compartment was vented to a passageway or to the outside, the nozzle operator could extinguish the fire either by: (1) applying water all the way down the hot passageway and into the compartment or (2) bending low and advancing to the compartment and then applying water for extinguishment. If the compartment was not vented, the nozzle operator could extinguish the fire only by staying low, advancing to the fire and then applying water for extinguishment. In both situations, the nozzle operator preferred the commercial nozzle over the Coast Guard APN as it offered multiple fog patterns for extinguishment, cooling and for forcing the steam, heat and smoke away from the operator.

Stationary Nozzle Tests

Data recorded during the stationary nozzle tests indicated that extinguishment occurred within 20 seconds for all these tests. This indicates that any of the nozzles, both commercial and Coast Guard approved, were effective for extinguishment if water could be applied to the fire.

8.0 SUMMARY

Nozzle Characteristics for Effective Marine Firefighting

Historically

Essential nozzle characteristics can be stated as follows:

a. The nozzle should be constructed of brass, bronze, or other material suited for use in a marine environment. Dissimilar materials which touch each other in the nozzle must be protected from galvanic corrosion.

b. The nozzle should be easy to operate with a bail type handle for controlling water flow. The flow should be off when the bail is pushed away from the operator and on when the bail is pulled toward the operator.

Operator Comments/Test Results

a. The nozzle should have a pistol grip handle attached to its underside for easy control.

b. It should have the capability of being adjusted from straight stream to a wide angle fog (180 degrees). This should be accomplished by the use of one hand and should not interfere with the nozzle while in use.

c. The fog pattern should pass the same quantity of water as the straight stream pattern when operating at the same pressure.

d. The fog pattern should be a solid cone with no break in the pattern. The fog patterns should project sufficient water inside the cone to force the flames away from the nozzle operator.

e. It should have a flush setting which will pass an object with a 3/16-inch or greater diameter. The flush setting should be capable of being operated with one hand by turning the nozzle tip 180 degrees counterclockwise. The size of the nozzle tip or flush setting is not the only factor in preventing nozzles from clogging. The nozzle should have an internal blade supported at two points for anchoring the nozzle stem inside the nozzle body. A blade which is supported at three points is more susceptible to clogging.

f. It should be design rated for a flow of 95 gpm at 100 psig. This provides a respectable flow at the pressures mandated by CFR requirements at the most remote hydrant.

g. The nozzle should be of the fixed flow rate at one design pressure. It should not be of the adjustable gallonage type such that the operator can adjust the size of the nozzle opening to increase or decrease the flow rate. This could result in the incorrect flow setting due to the inexperience of the nozzle operator. If the nozzles should be adjusted to the incorrect setting, the pressure could be appropriate but the flow could be insufficient for the fire conditions, or an incorrect setting could be used which would provide sufficient flow, but the pressure would not carry it to the fire.

h. Automatic nozzles should not be used as they do not provide sufficient improvement in firefighting performance to outweigh their potential for mechanical failure due to the complexity of their design. None of the automatics were

constructed of brass or bronze or of other materials for use in a marine environment.

i. Detents are not considered essential for indicating each different setting but they would be helpful for the operator to verifying what pattern is being used.

Control and Extinguishment

Commercial nozzles using either water or an AFFF solution are superior to the Coast Guard APN for the control and extinguishment of Class B deck fires. To date, commercial nozzles have not been compared to nozzles specifically approved by the Coast Guard for use with AFFF on board merchant vessels for combating Class B deck fires.

The compartment pretests indicated that the best firefighting technique for the nozzle operator was to stay low, advance to the fire and use a limited amount of water for extinguishment. Without adequate venting (a place for the nozzle operator to force the heat, smoke and steam), the application of water too early, and/or in too great a quantity created steam conditions which were forced back toward the operator. This forced him to withdraw from the area or seriously hampered his efforts. These tests also showed that the firefighter must be properly protected against the production of steam as well as the heat and combustion products or the firefighting effort could be seriously hampered.

The compartment test data indicated that the commercial nozzles on fog patterns were equivalent to the Coast Guard APN and applicator in extinguishing a small fire and and in cooling the room temperature to the same degree in equivalent times.

Nozzle Operation for Firefighting

The physical operation of each nozzle tested was basically the same: pick the nozzle up by the pistol grip, adjust the pattern, point it at the fire and pull the bail handle to permit the passage of water and then sweep the fire. If the nozzle should clog with debris, the operator would adjust the tip to its widest opening (flush setting), turn the water off and on, and or tap the nozzle on the deck, rotate the tip back to straight stream then to flush while turning the water off and on in each pattern. This procedure was repeated as often as necessary. This clearing procedure was essentially the same for all the nozzles.

Debris (rust)

It is obvious that a nozzle with a larger tip opening will pass a larger diameter steel ball. The major component of debris present in typical fire mains, however, is rust. The tests show-

ed that two of the commercial nozzles were more successful than the Coast Guard APN on fog pattern and the applicator in passing accumulations of rust. These two nozzles also had smaller tip openings than the Coast Guard APN and applicator. It is apparent that a nozzle design feature aided the Akron 3019 and Akron 3019M nozzles in breaking up the rust to enable it to pass through the two nozzles. It is suggested that the principal internal difference between these two nozzles which passed debris, and others which did not, is the use of the dual support for anchoring the nozzle stem. The other nozzles used a tri-support for tne nozzle stem which provides more obstructions to collect debris inside the body of the nozzle.

It is apparent that the slight reduction in the nozzle tip opening size for two commercial nozzles did not reduce their effectiveness in passing debris (rust). This would indicate that commercial nozzles with tip openings smaller than 3/8-inch diameter should not necessarily be rejected from approval as a marine firefighting nozzle.

Nozzle Effectiveness In Providing Operator Protection

The LPG fire tests indicated that all but one of the commercial nozzles on the wide fog pattern provided greater heat flux protection to the nozzle operator than did the Coast Guard APN and applicator. The commercial nozzles provide 21 percent more heat flux reduction at low flow rates (38-40 gpm), 29 percent more at medium flow rates (47-52 gpm) and 25 percent more at high flow rates (95 gpm).

The wide fog pattern of the commercial nozzles provided both operator protection and aided in control/extinguishment of a fire since it projected water toward the flames. The Coast Guard APN provided poor operator protection and poor control/extinguishment while the applicator provided the least effective operator protection and no projection of water forward to aid in control and extinguishment.

When using a narrow fog pattern, the commercial nozzles were equivalent to the Coast Guard nozzle in providing operator protection.

9.0 CONCLUSIONS

Commercial nozzles meeting the characteristics described in the above sections should be permitted for use on merchant vessels because when compared to the Coast Guard APN they provide:

a. straight patterns which have a substantially greater reach.

b. fog patterns which are adjustable from a narrow to a wide pattern (more than wide enough to protect firefighters at the nozzle) without the need of an applicator.

c. wide fog patterns (without gaps) which protect the nozzle operator and also project water at the fire for control and extinguishment.

d. the same application rate on both the straight stream and fog patterns.

e. a flush setting for passing debris which, when used in the technique described in this report, proved more successful than the slightly larger opening of the approved nozzle's fog pattern and its applicator.

f. superior protection in preventing heat flux from a fire in reaching the nozzle operator.

g. equivalent control and extinguishment times and cooling capabilities for compartment fires.

h. superior control and extinguishment times in controlling deck fires with water or AFFF solution.

Rust is the principle debris problem on board merchant vessels. Rather than test nozzles regarding whether they pass a certain size steel ball (which is obviously not found in the ship's fire main), a performance specification should be prepared which evaluates nozzles on the passage of rust as one of the approval criteria.

The traditional shipboard firefighting technique of having two hoseline teams in which the second team's sole purpose is to use the applicator to protect the first firefighting team should be changed. Instead, each hoseline team should have a commercial nozzle and be permitted to attack the fire side-by-side. This would provide twice the firefighting application and the versatility of the adjustable fog patterns would allow each nozzle team the capability of protecting themselves and each other.

Compartment fires should be vented to provide an area for the firefighter to force the smoke, heat and steam so that he may advance to the fire for extinguishment. If the area cannot be vented, the firefighter should stay low, advance to the fire and then apply a limited quantity of water for extinguishment. Copious amounts of water applied too early can produce sufficient steam to prevent his entry or if applied within the compartment can force his withdrawal before extinguishment is completed. This statement holds true regardless of how much protective gear the firefighter is wearing.

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APPENDIX A
DATA FOR RANGE/PATTERN/DEBRIS TESTS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press/Flow+ (psig/gpm)	Range (ft)	Pattern Type	Pattern Dia. (ft)	Debris Rust (% Pass)	Debris Steel Ball	Ambient Conditions Baro Press (mm/Hg)	Wind Dir.	Wind Speed (mph)	Temp. (deg F)
A1	AKRON 3019M	100/60	100/60	79	st st	3	100	NP	30.10	SW	<8	78
A2	AKRON 3019M	100/60	75/52	71	st st	3	100	NP	30.10	S	<8	78
A3	AKRON 3019M	100/60	50/42	61	st st	3	100	NP	30.10	SW	<8	78
A4	AKRON 3019M	100/60	100/60	*	w/fog	11	100	NP	30.10	SE	<8	80
A5	AKRON 3019M	100/60	75/52	*	w/fog	11	100	NP	30.10	SE	<8	80
A6	AKRON 3019M	100/60	50/42	*	w/fog	11	100	NP	30.12	SE	<8	80
A7	AKRON 3019M	100/60	100/60	**	n/fog	8	0	NP	30.10	SE	<8	98
A8	AKRON 3019M	100/60	75/52	**	n/fog	8	80	NP	30.10	SE	<8	98
A9	AKRON 3019M	100/60	50/42	**	n/fog	8	80	NP	30.10	SE	<8	98
A10	AKRON 3019	100/95	100/95	107	st st	3	100	NP	30.12	SW	<8	96
A11	AKRON 3019	100/95	75/83	95	st st	3	100	NP	30.12	SW	<8	96
A12	AKRON 3019	100/95	50/68	71	st st	3	0	NP	30.10	SW	<8	96
A13	AKRON 3019	100/95	100/95	*	w/fog	11	100	NP	30.12	SW	<8	95
A14	AKRON 3019	100/95	75/83	*	w/fog	11	100	NP	30.12	SW	<8	95
A15	AKRON 3019	100/95	50/68	*	w/fog	11	100	NP	30.12	SW	<8	95
A16	AKRON 3019	100/95	100/95	**	n/fog	8	100	NP	30.12	S	<8	95
A17	AKRON 3019	100/95	75/83	**	n/fog	8	100	NP	30.12	S	<8	95
A18	AKRON 3019	100/95	50/68	**	n/fog	8	0	NP	30.12	S	<8	95
A19	ELKHART SFL-B	100/60	100/60	79	st st	3	0	NP	30.10	SE	<8	92
A20	ELKHART SFL-B	100/60	75/52	68	st st	3	0	NP	30.11	SE	<8	92
A21	ELKHART SFL-B	100/60	50/42	61	st st	3	0	NP	30.12	S	<8	92
A22	ELKHART SFL-B	100/60	100/60	*	w/fog	10	0	NP	30.08	SW	<8	94
A23	ELKHART SFL-B	100/60	75/52	*	w/fog	10	100	NP	30.10	SW	<8	94
A24	ELKHART SFL-B	100/60	50/42	*	w/fog	10	0	NP	30.10	S	<8	94
A25	ELKHART SFL-B	100/60	100/60	**	n/fog	8	0	NP	30.16	S	<8	94
A26	ELKHART SFL-B	100/60	75/52	**	n/fog	8	0	NP	30.14	S	<8	94
A27	ELKHART SFL-B	100/60	50/42	**	n/fog	8	5	NP	30.14	S	<8	94

NOTE:
* = The wide fog pattern was measured at a 5 foot distance from the nozzle.
** = The narrow fog pattern was measured at an 11 foot distance from the nozzle.
NP = Not Passed
P = Passed
+ = Flow varied by plus or minus 3 gallons per minute.

APPENDIX A (cont'd)
DATA FOR RANGE/PATTERN/DEBRIS TESTS

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press/Flow+ (psig/gpm)	Range (ft)	Pattern Type	Pattern Dia. (ft)	Debris Rust (% Pass)	Debris Steel Ball	Ambient Conditions Baro Press (mm/Hg)	Ambient Conditions Wind Dir.	Ambient Conditions Wind Speed (mph)	Ambient Conditions Temp. (deg F)
A28	ELKHART SFL-GN-95	100/95	100/95	103	st st	3	100	NP	30.12	SW	<8	98
A29	ELKHART SFL-GN-95	100/95	75/83	93	st st	3	0	NP	30.12	SW	<8	98
A30	ELKHART SFL-GN-95	100/95	50/68	69	st st	3	0	NP	30.10	SW	<8	98
A31	ELKHART SFL-GN-95	100/95	100/95	*	w/fog	9	95	NP	30.12	SE	<8	98
A32	ELKHART SFL-GN-95	100/95	75/83	*	w/fog	9	0	NP	30.10	SE	<8	98
A33	ELKHART SFL-GN-95	100/95	50/68	*	w/fog	9	0	NP	30.10	SE	<8	98
A34	ELKHART SFL-GN-95	100/95	100/95	**	n/fog	8	0	NP	30.14	SW	<8	96
A35	ELKHART SFL-GN-95	100/95	75/83	**	n/fog	8	0	NP	30.14	S	<8	96
A36	ELKHART SFL-GN-95	100/95	50/68	**	n/fog	8	0	NP	30.14	S	<8	96
A37	CG APN	100/117	117/100	71	st st	3	90	P	30.10	S	<8	98
A38	CG APN	100/117	75/99	59	st st	3	100	P	30.10	SE	<8	98
A39	CG APN	100/117	50/81	55	st st	3	100	P	30.10	SE	<8	98
A40	CG APN	100/55	100/55	**	fog	8	100	P	30.11	SW	<8	96
A41	CG APN	100/55	75/47	**	fog	8	0	P	30.12	S	<8	96
A42	CG APN	100/55	50/38	**	fog	8	0	P	30.10	SW	<8	96
A43	CG APN applicator	100/54	100/54	*	w/fog	25	0	P	30.09	S	<8	98
A44	CG APN applicator	100/54	75/47	*	w/fog	22	0	P	30.10	SE	<8	98
A45	CG APN applicator	100/54	50/38	*	w/fog	20	0	P	30.10	SW	<8	98
A46	TFT BGH-125F	80/90	80/90	95	st st	3	5	NP	30.10	SW	<8	98
A47	TFT BGH-125F	80/90	75/80	89	st st	3	5	NP	30.15	S	<8	98
A48	TFT BGH-125F	80/90	50/40	61	st st	3	5	NP	30.12	SW	<8	98
A49	TFT BGH-125F	80/90	80/90	*	w/fog	12	5	NP	30.09	S	<8	98
A50	TFT BGH-125F	80/90	50/40	*	w/fog	12	5	NP	30.10	SE	<8	98
A51	TFT BGH-95	100/95	100/95	*	w/fog	7	5	NP	30.08	SW	<8	96
A52	TFT BGH-95	100/95	75/83	*	w/fog	7	5	NP	30.07	S	<8	96
A53	TFT BGH-125F	80/90	80/90	**	n/fog	7	5	NP	30.05	SW	<8	96
A54	TFT BGH-125F	80/90	50/40	**	n/fog	7	5	NP	30.07	SE	<8	96
A55	TFT BGH-95	100/95	100/95	*	n/fog	7	0	NP	30.12	S	<8	95
A56	TFT BGH-95	100/95	75/83	*	n/fog	7	0	NP	30.13	S	<8	95
A57	TFT BGH-95	100/95	50/68	*	n/fog	7	0	NP	30.12	SW	<8	95
A58	ELKHART SM-10-FBC	105/125	100/100	*	n/fog	6	0	NP	30.06	SW	<8	94
A59	ELKHART SM-10-FBC	105/125	75/48	**	w/fog	16	0	NP	30.07	S	<8	95
A60	FEECON-NAVY	100/95	100/95	103	st st	3	0	P	30.12	SW	<8	95
A61	FEECON-NAVY	100/95	75/83	95	st st	3	0	P	30.10	SW	<8	95
A62	FEECON-NAVY	100/95	50/68	67	st st	3	0	P	30.11	SW	<8	95

NOTE:
* = The wide fog pattern was measured at a 5 foot distance from the nozzle.
** = The narrow fog pattern was measured at an 11 foot distance from the nozzle.
NP = Not Passed
P = Passed
+ = Flow varied by plus or minus 3 gallons per minute.
st st = straight stream
w/fog = wide fog
n/fog = narrow fog

APPENDIX B
TEST SCHEDULE FOR LPG FIRES

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern	
B26	AKRON 3019M	100/60	100	60	w/fog	
B5	AKRON 3019M	100/60	75	52	w/fog	
B14	AKRON 3019M	100/60	50	42	w/fog	
B11	AKRON 3019	100/95	100	95	w/fog	
B23	AKRON 3019	100/95	75	83	w/fog	
B4	AKRON 3019	100/95	50	68	w/fog	
B19	ELKHART SFL-B	100/60	100	60	w/fog	
B22	ELKHART SFL-B	100/60	75	52	w/fog	
B12	ELKHART SFL-B	100/60	50	42	w/fog	
B10	ELKHART SFL-GN-95	100/95	100	95	w/fog	
B16	ELKHART SFL-GN-95	100/95	75	83	w/fog	
B9	ELKHART SFL-GN-95	100/95	50	68	w/fog	
B2	CG APN	100/55	100	55	fog	
B20	CG APN	100/55	75	47	fog	
B18	CG APN	100/55	50	38	fog	
B15	CG APN applicator	100/54	100	54	w/fog	
B8	CG APN applicator	100/54	75	47	w/fog	
B1	CG APN applicator	100/54	50	38	w/fog	
B32	TFT BGH-125F	80/90	75	80	w/fog	
B33	TFT BGH-125F	80/90	50	40	w/fog	
B34	ELKHART SM-10-FBC	105/125	75	48	w/fog	
B35	FEECON-NAVY	100/95	100	95	w/fog	
B36	FEFCON-NAVY	100/95	50	68	w/fog	
B31	TFT BGH-95	100/95	100	95	w/fog	
B28	AKRON 3019M	100/60	75	52	n/fog	
B3	ELKHART SFL-B	100/60	75	52	n/fog	
B7	TFT BGH-60	100/60	75	52	n/fog	
B29	FEECON-NAVY	100/95	75	83	n/fog	
B30	CG APN	100/55	75	47	n/fog	
B17	CG APN	100/55	50	38	n/fog	
B37	AKRON 3019M	100/60	75	52	n/fog	3.00% AFFF
B38	TFT BGH-60	100/60	75	52	n/fog	3/25% AFFF
B39	ELKHART SFL-B	100/60	75	52	n/fog	2.75% AFFF

NOTE: w/fog = wide fog
n/fog = narrow fog
\+ = Flow varied by plus or minus 3 gallons per minute.

APPENDIX C
TEST SCHEDULE FOR COMPARTMENT FIRES

Extinguishment time: less than or equal to 20 seconds for all tests.

Test No.	Nozzle	Mfgr's Design (psig/gpm)	Test Press (psig)	Test Flow+ (gpm)	Pattern
C36	AKRON 3019M	100/60	50	42	n/fog
C14	AKRON 3019M	100/60	50	42	n/fog
C35	AKRON 3019M	100/60	75	52	n/fog
C30	AKRON 3019M	100/60	75	52	n/fog
C27	AKRON 3019	100/95	50	68	n/fog
C11	AKRON 3019	100/95	50	68	n/fog
C15	AKRON 3019	100/95	75	83	n/fog
C26	AKRON 3019	100/95	75	83	n/fog
C28	ELKHART SFL-B	100/60	50	42	n/fog
C23	ELKHART SFL-B	100/60	50	42	n/fog
C33	ELKHART SFL-B	100/60	75	52	n/fog
C25	ELKHART SFL-B	100/60	75	52	n/fog
C18	ELKHART SFL-GN-95	100/95	50	68	n/fog
C21	ELKHART SFL-GN-95	100/95	50	68	n/fog
C31	ELKHART SFL-GN-95	100/95	75	83	n/fog
C17	ELKHART SFL-GN-95	100/95	75	83	fog
C32	CG APN	100/55	50	38	fog
C12	CG APN	100/55	50	38	fog
C7	CG APN	100/55	75	47	fog
C34	CG APN	100/55	75	47	fog
C22	CG APN applicator	100/54	50	38	w/fog
C24	CG APN applicator	100/54	50	38	w/fog
C16	CG APN applicator	100/54	75	47	w/fog
C8	CG APN applicator	100/54	75	47	w/fog
C1	TFT BGH-125F	80/90	50	40	n/fog
C2	TFT BGH-125F	80/90	75	80	n/fog
C3	TFT BGH-95	100/95	50	68	n/fog
C4	TFT BGH-95	100/95	75	53	n/fog
C5	FEECON-NAVY	100/95	50	68	n/fog
C6	FEECON-NAVY	100/95	75	83	n/fog

NOTE: w/fog = wide fog
n/fog = narrow fog
+ = Flow varied by plus or minus 3 gallons per minute.